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OPTIMAL PATTERNS FOR THE TRANSPORTATION OF EXPORT COMMODITIES WITHIN NIGERIA

by

© PATIENCE CHINYELU MONANU

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
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OF DOCTOR OF PHILOSOPHY

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FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled OPTIMAL PATTERNS FOR THE TRANSPORTATION OF EXPORT COMMODITIES WITHIN NIGERIA submitted by PATIENCE CHINYELU MONANU in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY in GEOGRAPHY.

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ABSTRACT

The transport sector has been a major area of investment by the Nigerian government and many improvement projects have been planned to take place during the current National Development Plan period (1975-1980). Although most countries of the world operate their transport facilities at a deficit, the losses impose a relatively heavier drain on less developed economies like that of Nigeria. It is therefore important to make the most economical use of available scarce resources by shipping efficiently on existing facilities in order to justify the heavy investments in this sector of the economy.

The Transportation Problem of linear programming was employed in investigating the nature of short-run efficiency in the pattern of shipping cocoa and palm kernels to the ports or to processing industries within Nigeria. The aim of the study was to obtain a quantitative impression of how the shipping bill of the Commodity Boards could be reduced. It also illustrates the effects which the modal choice decision for the shipping of these commodities has on the country's economy, and the relevance of these decisions for transport co-ordination in Nigeria.

The basic data required by the model consists of the quantities of cocoa and palm kernels purchased at each origin (Si), the demand for these commodities at the ports or at the processing industries (Dj) and the freight rate by each mode of transport on all available links and the

transhipment costs (Tij). Data on these variables in 1976/77 were obtained from the Commodity Boards, the Produce Inspection Division of the Ministry of Agriculture, the Nigerian Railway Corporation and the Central Water Transportation during the field work in Nigeria. Data on the road freight rate of the transport firms were either obtained from field work or estimated.

The shortest paths obtained from modelling the transportation network as a Transhipment Problem was employed, as if they were direct links, in the Transportation Problem in order to obtain the optimal pattern of shipments. The shortest paths that were selected in the optimal solution were then re-interpreted link-by-link in order to illustrate the actual routes over which shipments were made in the optimal model.

The results of both the cocoa and palm kernel shipping problems indicate that apparently sub-optimal shipments which were more expensive to the system were being made because of the nature of the demand for cocoa and palm kernels at the respective demand points. When shipments to one major external destination was considered, the optimal shipment pattern obtained is more representative of the shipping cost function for the individual shippers.

The total cost of all the models which employed the road transport freight rates of the transport firms (Cost1 Model) were lower that the total cost of equivalent models which employed the road transport differential of the

Commodity Boards (Cost2 Model) for all shipments of cocoa and palm kernels. This indicates that the Boards would save on shipping costs by employing the services of the carriers for shipping these commodities to the demand points instead of paying the licenced buying agents to undertake the shipments. In all cases, Cost2 Model makes greater use of the cheaper railway and waterway modes than Cost1 Model which makes more use of shipments by road.

These findings are contrary to the present pattern of marketing and transporting export commodities in Nigeria. The Commodity Boards continue to incur higher shipping costs by employing the agents to transport the commodities instead of the carriers. These higher costs can only be justified by other non-economic functions, especially 'bush collection', which the agents perform for the Boards.

The major limitation of the research is that there were no data on actual shipments to the ports from the respective origins against which the optimal pattern obtained from the study can be compared. Another limitation is that since only cocoa and palm kernels which are grown mainly in the southern part of Nigeria are considered, the results and recommendations do not apply to the whole country. However, the study provides an insight into the basic issues involved.

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1. Chapter One INTRODUCTION

1.1 Introduction

In most developing countries a wide range of transport facilities already exists. Technologically, these may range from primitive footpaths and dirt roads with human or animal porterage to superhighways, railways, and aircraft. Since the choices open to developing countries cover a wide range of possibilities, it is important to ensure that their transportation needs are selected efficiently from the wide range of choices open to them. It is also necessary to take each nation's needs and resources into consideration.

Although most countries of the world operate their transport facilities at a deficit, the losses impose a relatively heavier drain on less developed economies like that of Nigeria. In some developing countries, losses in the transportation sector absorb a large share of the government tax revenue, thus limiting the capacity of the government to meet urgent needs in other sectors. The effect of this can be more devastating when we consider the fact that the transport sector is not a separate sector of the economy but a link among other sectors. Therefore, it is important that efficient use is made of existing facilities in order to ensure the most economical use of scarce resources.

Various interrelated mechanisms are attributed to the role that transportation plays in economic development. Transportation leads to increased specialization in production, encourages a high rate of capital formation, acts as a control on factor mobility and provides increased accessibility, thereby promoting economic development. The role that transportation plays in economic development is very subtle and quite often, there are no clear indications of how it affects the overall economy because it may be operating concomitantly with many other factors. It has been indicated that where a nation is deficient in the factors condusive to growth, no amount of transport investment can create the dynamism that is necessary for economic development. However, whatever role of transportation is being considered, the efficiency of usage is critical and this is the major concern of this study.

The transport sector has, over the years, been a major area of investment by the Nigerian government. In the Second National Development Plan of Nigeria (1962-1968), the transport sector received the largest single allocation, while in the Third National Development Plan (1975-1980), it received about 22% of total allocation. Improvements planned for the current plan period include the construction or improvement of 31,000 kilometers of major roads, the first phase of a new railway system and the construction of eighteen new shipping berths, six berths at Apapa port and four berths each at Warri, Calabar, and Port Harcourt. These are intended to reduce the adverse effects of port congestion on the economy of Nigeria.

In 1970/71, the country experienced port congestion problems due to the bottlenecks in the evacuation processes at the ports which impeded quick turn-around time for the shipping vessels. Again in 1974, Lagos port experienced serious congestion problems caused by an unprecedented and unscheduled influx of ships which arrived simultaneously, all demanding the limited berthing facilities. Although there are no alternatives to rationing scarce capacity, improved staggering of vessels arrival and the redistribution of cargo throughput through the various ports may help to improve the situation.

Generally, port congestion arises from bottlenecks in one or a combination of the integral parts of port operation which consists of the shipping vessels, the cargo and the loading or off-loading processes. There are several strategies and measures which could be designed to study port congestion problems in order to assess the impact of all the factors involved. This study is related only to the evacuation patterns for Nigeria's export commodities to the major seaports, as these are reflected on the basic transportation infrastructure within the country.

One of the major policy issues confronting the Federal Government of Nigeria in the transportation sector is the need for greater co-ordination among the various transport modes. This demands a rational approach in making investment decisions in this sector in such a way that scarce funds are not invested without proper consideration for the interdependence of the various modes. It has been noted that in some cases, funds have been invested in providing facilities which are not being adequately utilized, sometimes because such facilities are not related to the needs of the transport network as a whole.

It has been suggested so many times that the government should take necessary measures to resolve the unhealthy competition between the railways and the roads in order to allow them to provide complimentary services. It is also often reccmmended that the governments should take measures to ensure that the various Commodity Boards employ the most rational mode of transport in moving their commodities to the ports. This study may indicate an approach for using the Commodity Boards as a leverage for transport co-ordination. It may also provide some guidiance for efficient transport utilization in the country if the Boards can reduce their shipping bills by making more appropriate modal choice decisions.

In order to identify short-run inefficiencies in the pattern of shipping export commodities in Nigeria, an optimizing approach to network utilization was employed. There are many formulations of optimization models reflecting different initial conditions, system behaviours and primary objectives and constraints. The particular formulation used depends on the nature of the technological, institutional and geographical context of planning problem for which the model has been designed.

The optimization model used in this study for investigating the optimal patterns for shipping export commodities in Nigeria is the Transportation Problem of linear programming. It is one of the numerical optimization procedures which attempt to incorporate significant theoretical relationships that are devised to provide computationally feasible solutions to real planning problems. These models contrast sharply with other types of optimization models that isolate and rigourously analyse a smaller set of factors and have the ultimate aim of displaying analytical elegance rather than providing specific numerical solutions to practical planning problems.

The fact that economic and non-economic transportation objectives are competing and often incompatible raises some serious problems in developing optimal transportation networks. A fundamental question regarding the relevance of optimization models to transportation systems planning is whether rigorous optimization methods can be applied effectively in situations where the systems are relatively poorly understood and very little data are available as in developing countries. It can however be argued that an approximate solution to a relevant problem may be more useful in such situations than an exact solution to an irrelevant problem. Many operations research models are of the later type and the reseachers who employ the optimization techniques for solving specific planning problem are not claiming to deliver more than is possible. In fact, they should always emphasize that the approach is indicative of a modest scientific approach to transportation planning problems. It provides information on a range of feasible and reasonably efficient alternatives before the subjective decision that is inherent in transportation choice alternatives is made.

Important consideration must also be given to the subsidy issue as this may further complicate the determination of the optimal transportation network. Generally, subsidies considerably reduce the effect of the real cost of transportation. The transportation sector in Nigeria is structured in such a way that with the exception of roads, all other major modes of transport are run by statutory bodies. In most developing countries, these statutory bodies are established in order to stimulate and accelerate national economic development under conditions of capital scarcity and structural defects in private business organization. Unfortunately, most of these statutory corporations are not responsive to the changing needs of the growing economies of these countries. This situation gives rise to inefficiencies and other general problems on other policy issues that characterize such corporations.

In this study, the Transportation Problem of linear programming is employed in the minimization of shipping costs for cocoa and palm kernels in order to obtain an optimal shipment pattern for the commodities. This is of course, subject to the constraint that the demand requirements at all the demand points are satisfied without violating the availabilities of these commodities at the producing regions. The cost data that are employed in the study are the shipping costs, which consists of the usual terminal rates and the actual freight rates, and the transhipment costs.

Apart from production and processing costs, the other costs involved in export commodity marketing and transportation include the costs of warehousing at the demand points, the ports or the supply regions and storage costs. These are not considered in this study. If the cost of warehousing is constant in all the warehouses, the addition of warehousing costs will not alter the optimal shipping pattern. Rather, the total minimum cost of the optimal pattern will increase by a fixed sum.

1.2 Objectives of the Study

The main objective of this research is to investigate the optimal spatial pattern of inland transportation of two major export commodities namely, cocoa and palm kernels, in Nigeria. These commodities are transported to the seaports by road, rail and inland waterways. The major goals which the study attempts to accomplish are as follows:

1. To provide a case study for developing countries in general and for Nigeria in particular. There is not yet any study concerned with the inefficiencies associated with the pattern of shipping export commodities within the country despite the fact that the competitiveness of

Nigeria's major export crops abroad depends largely on the degree to which these inland shipping costs can be reduced. This is particularly important because the shipping costs constitute the single largest expense of the Commodity Boards. This research may help to fill this gap by applying an adaptation of the Transportation Model to the movement of cocoa and palm kernels in Nigeria. The study aims at determining the optimal pattern for the transportation of these two commodities in Nigeria when the demand for the commodities at the processing industries, the major seaports or the outside world are the major constraints.

2. To identify any bottlenecks in the present pattern of evacuation of cocoa and palm kernels in Nigeria. The bottlenecks are considered in relation to the demand for these commodities at the ports. It may be possible to indicate whether there are any ports in which excess or insufficient demand for the commodities are causing excess transportation costs to be incurred in the system. In this way, the results can also give a quantitative indication of how the transport bill of the Commodity Boards can be reduced.
3. To illustrate the effects which the modal choice decisions for the transportation of these export commodities has on the economy, and the relevance of these decisions to transport co-ordination in Nigeria. The model allows for the possiblity of transhipment

between the various modes at the transhipment points. In this way, it allows these modes to provide complimentary services at the expense of the appropriate transhipment costs. The results obtained from this may lead to recommendations for more appropriate modal choice decisions in the transportation policy of Nigeria.

4. To demonstrate the application of a linear programming model which is more extensive in its coverage of modes and commodities than models currently being used. It is a multi-mode multi-commodity transhipment model. It is possible to extend this model to take link capacity into consideration. When capacity is considered, the advantage of interpreting the dual enables the model to be employed in considering the effects of additional links on the entire system. The study adds another practical example to the empirical literature on the transportation problem in which there are two or more modes of transport and several commodities.

1.3 Organization of the Study

Chapter II presents a general background to the economy of Nigeria. It discusses the development of the transportation network and also the role of transportation in the marketing of export commodities in the country. Previous studies related to transport optimization in Nigeria are presented and the relevance and limitations of the research are outlined.

Chapter III discusses the Classical Transportation Problem and its extensions as well as the Transhipment Problem and the relevant theoretical literature associated with them. It also presents a discussion of the objective function and the solution algorithms used for solving the transportation problem.

Chapter IV presents the method of developing the formal model used in the study and then a discussion of the underlying economic model.

Chapter V indicates the sources of data used in the analysis. It presents a brief description of the variables as given and any major modifications of them adopted in the study. Some conceptual and data problems are also discussed.

Chapter VI presents the results of the analysis.

Chapter VII presents a discussion of the findings and draws conclusions from them. In addition, recommendations for future research are made.

2. Chapter Two THE NIGERIAN TRANSPORTATION INFRASTRUCTURE AND PREVIOUS STUDIES

2.1 Introduction

Transportation constitutes one of the major features of the economic development of Nigeria. The opening of the country's vast area by various forms of transport resulted in economic growth which in turn stimulated further demand for transportation. The development of the national transport network was intended to provide adequate transportation services for the growing and changing economy of Nigeria in a way that was consistent with other public or national objectives, such as the opening and binding together of the nation. In recent years, the country has experienced an unprecedented general economic boom, resulting in increased diversification of industrial and commercial activities. Consequently, the movement of people and goods is critical to the continued development of the country's economy.

This chapter presents a general background to the role of transportation in Nigeria's economy. It discusses the three modes of transportation utilized for freight movement which have played and will continue to play significant roles in the social, political and economic development of Nigeria. These modes, namely, road, rail and waterways are discussed with regard to their historical development, their impact on the economy and their prospects for further development under the Third National Development Plan.

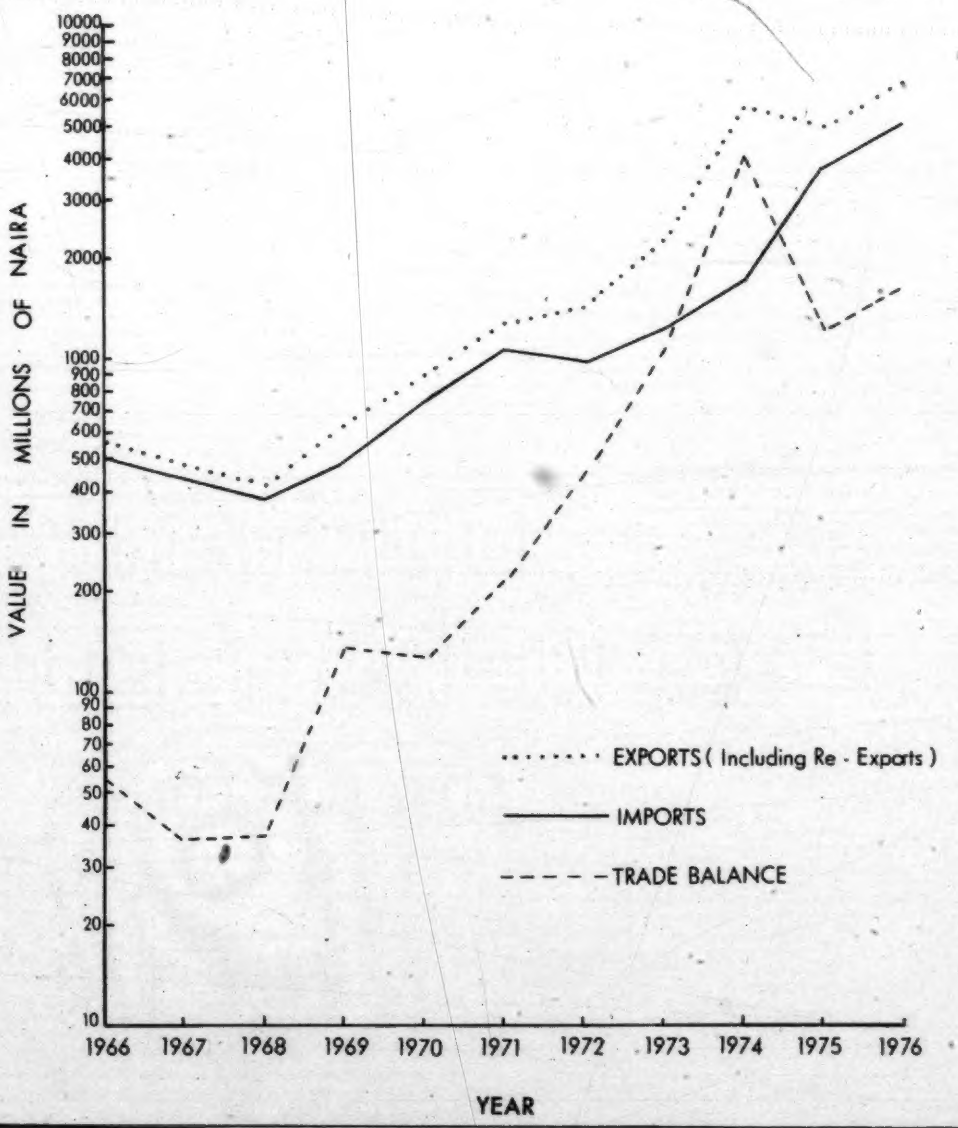
2.2 Background to the Economy of Nigeria

Nigeria's economic development was based primarily on the expansion of peasant production for export. Until 1960, Nigeria's exchange economy was based mainly on exporting a few agricultural commodities and importing a wide range of manufactured goods. Figure 1 illustrates how the increase in the value of yearly exports has enabled the country to maintain a favourable balance of trade.

Since 1960 however, crude oil production and export has become the booming component of the Nigerian economy. Figure 2 demonstrates the dominance of petroleum in both quantity and value in Nigeria's export trade. In spite of its dominance however, agricultural exports will continue to play an important role in Nigeria's economy since over 70% of the population of the the country is employed in agriculture.

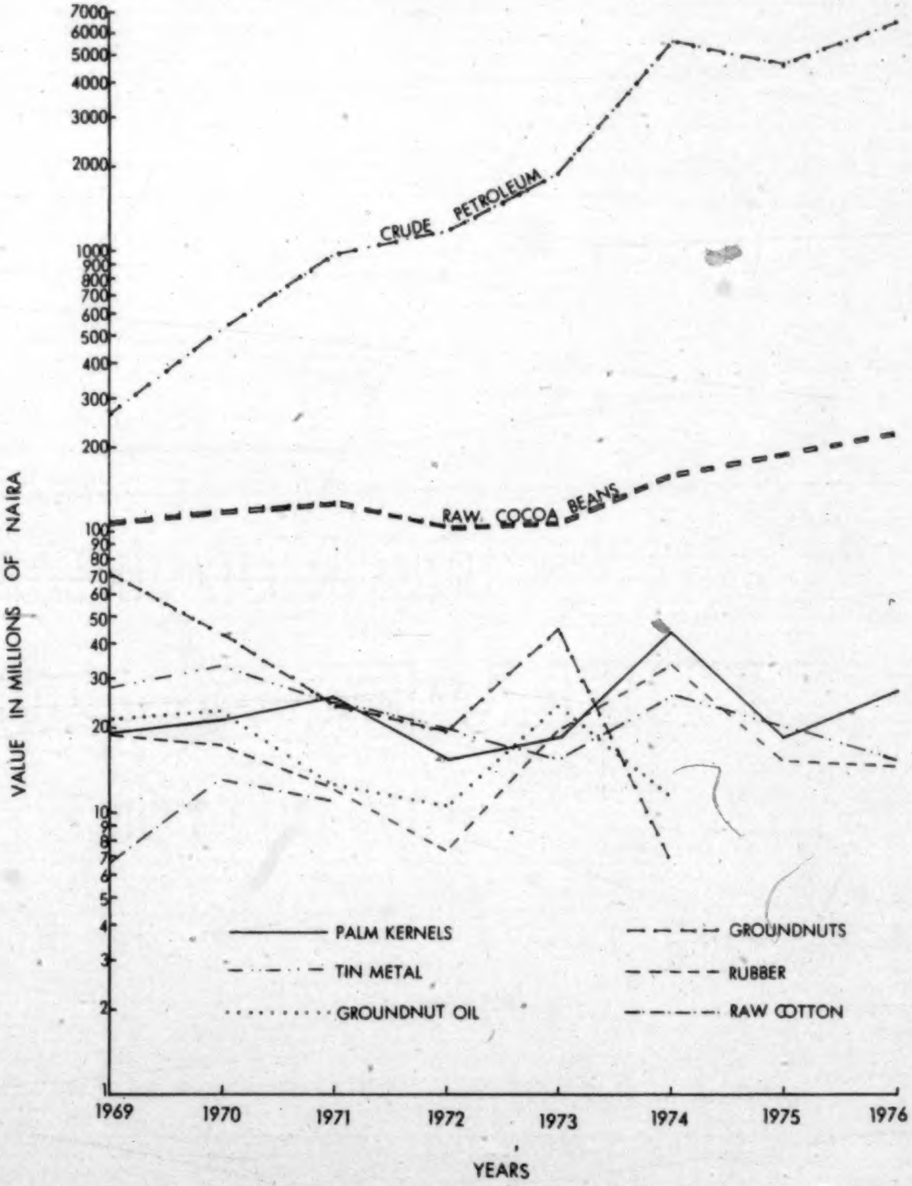
Figure 3 shows the spatial distribution pattern of the major export crops of Nigeria which is fairly simple. Groundnuts are produced mainly in the north, palm oil and palm kernels are produced mainly in the south east, and cocoa is produced mainly in the west. Table 1 illustrates the relative importance of these export commodities in the economy of the country. In 1966, groundnuts, palm produce, and cocoa contributed 21, 14, and 12% of the total

FIGURE 1. VALUE OF ALL YEARLY IMPORTS AND EXPORTS (1966 - 1976)



Source: Review of External Trade, Federal Office of Statistics, Lagos, Nigeria, 1976, page 35.

FIGURE 2. VALUE OF PRINCIPAL EXPORT COMMODITIES (1969 -1976)



Source: Review of External Trade, Federal Office of Statistics, Lagos, Nigeria, 1976, page 39.

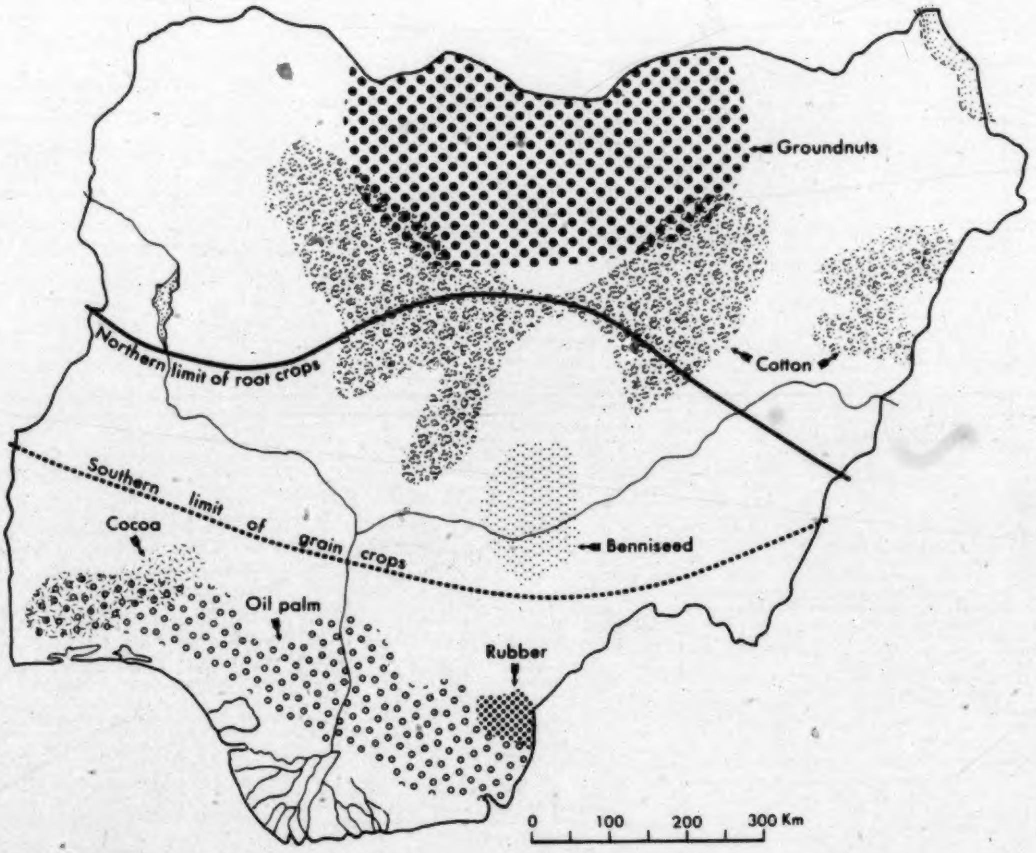

Groundnuts
Cotton
Northern limit of root crops
Southern limit of grain crops
Benniseed
Cocoa
Oil palm
Rubber
0
100
200
300 Km

FIGURE 3 SPATIAL DISTRIBUTION OF MAJOR EXPORT CROPS

TABLE 1. RELATIVE PERCENTAGE OF MAJOR EXPORT COMMODITIES OF TOTAL EXPORTS OF NIGERIA (Value in N Million)

Commodity	Percentage of Total Exports				
	1972	1973	1974	1975	1976
Groundnuts	1.4	2.0	0.1	*	*
Groundnut Oil	0.8	1.0	0.2	*	*
Groundnut Cake	0.4	0.8	0.1	*	0.1
Cocoa Beans	7.1	5.0	2.7	3.7	3.2
Cocoa Butter	0.7	0.7	0.4	0.4	0.2
Other Cocoa Products	0.1	0.2	0.1	0.1	0.1
Crude Petroleum Oil	82.7	83.5	92.8	92.8	93.8
Palm Kernels	1.1	0.8	0.7	0.4	0.4
Palm Kernel Oil	0.4	0.3	0.4	0.2	0.1
Palm Kernel Cake	0.1	0.1	*	*	*
Palm Oil	*	*	*	0.1	*
Rubber	0.5	0.8	0.6	0.3	0.2
Raw Cotton	*	0.2	*	*	*
Cotton Seed	0.2	*	*	*	*
Tin Metal	1.4	0.7	0.5	0.4	0.2
Hides and Skins	0.5	0.6	0.2	0.1	0.1
Coffee	0.1	0.1	*	*	0.1
Timber and Plywood	0.6	0.6	0.2	0.1	*
Total Major Exports	98.1	97.4	99.0	98.6	98.5
Other Commodities	1.9	2.6	1.0	1.4	1.5
All Domestic Exports	100.0	100.0	100.0	100.0	100.0

N. B. * Indicates Negligible.

Source : Review of External Trade, Federal Office of Statistics, Lagos, Nigeria. 1976, page 21.

export earnings, respectively. But, in the last five years, only cocoa and palm kernels have made significant contributions to total export earnings. Their export volumes have remained relatively constant between 1960 and 1976. Unfortunately, the export of groundnuts and palm oil has stopped completely. This has been attributed to declining output, increasing domestic consumption and absorption by local industries. Therefore, unprocessed cocoa and palm kernels are the export commodities considered in this study.

2.2.1 Export Crop Production in the Economy of Nigeria

Cocoa was introduced into the southern forestlands of Nigeria in the late 19th Century and the first export was in 1892. Cocoa production rose rapidly due to widespread cultivation of the crop in large plantations throughout Yorubaland, comprising the present Ondo, Oyo, and Ogun States (Figure 4). From the major cocoa growing areas, cocoa cultivation expanded to other places in southern Nigeria and the quantity of cocoa exported increased steadily.

Since 1960, the quantity of cocoa exported by Nigeria has been decreasing. This has been attributed to the declining productivity of the cocoa tree due to age and disease, and to shortage of farm labour. Fortunately, increasing market prices more than compensate for the decrease in output. Already, extensive programmes of cocoa regeneration have been undertaken and more have been planned to take place during the current Third National Development

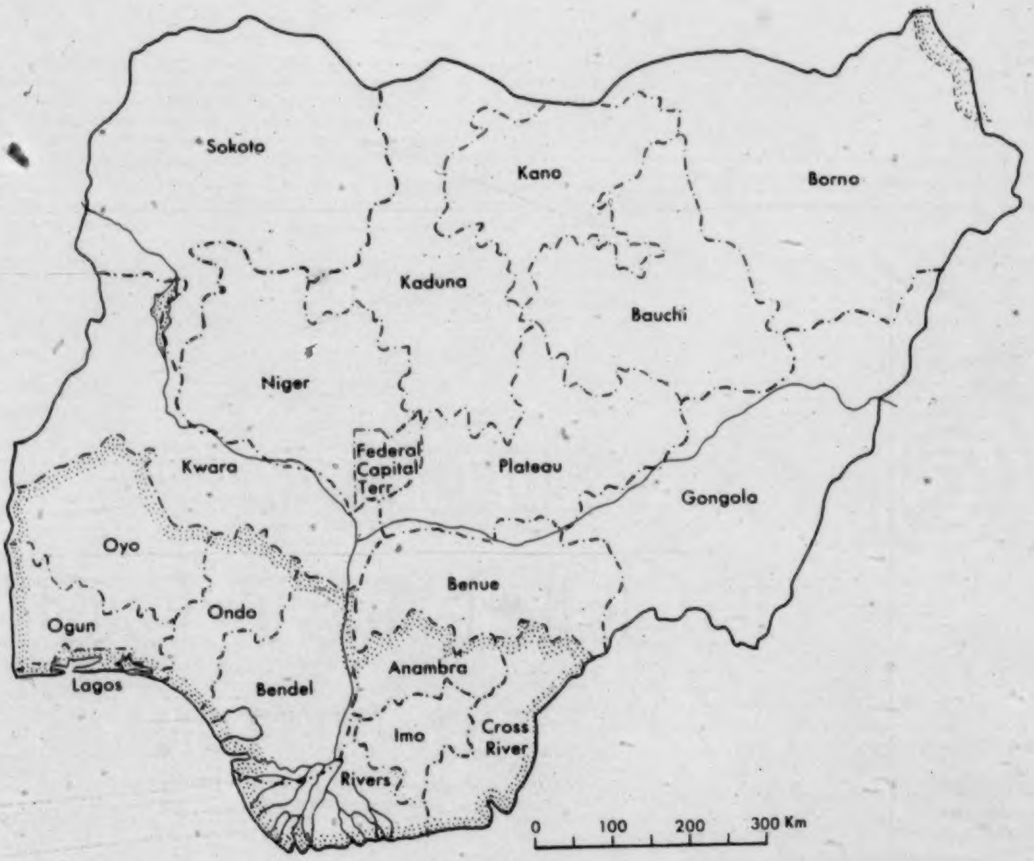

Sokoto
Kano
Borno
Kaduna
Bauchi
Niger
Kwara
Federal Capital Terr.
Plateau
Gongola
Oyo
Benue
Ogun
Ondo
Anambra
Lagos
Bendel
Imo
Cross River
Rivers
0
100
200
300 Km

FIGURE 4 ADMINISTRATIVE STATE SYSTEM AND THE STUDY AREA

Plan period. Meanwhile, farmers are being encouraged to plant other cash crops such as citrus, coffee and cashew trees in addition to cocoa in order to avoid the economic problems that are often associated with monoculture.

Palm trees grow throughout the southern forests but palm kernel production is most important in the south eastern states of Imo, Anambra and Cross River states. Bendel state and the Western states also produce palm kernels for export. Figure 4 shows the nine southern states that comprise the area of study.

The importance of the oil palm industry in the economy derives from its simultaneous use as basic food and as an export crop. Consequently, when world prices fall, the producers still have a large and growing market within the country. The palm tree has several economic uses but the most important two are palm oil (a vital source of fat and oil in the diet of many Nigerians) and palm kernels (used for the manufacture of soap and margarine). There are some oil palm plantations (both government and private) but these account for a very small percentage of total production which still comes predominantly from wild palms. Until the introduction and use of mills in the 1950's, Nigerian palm oil was characterized by low quality due to poor harvesting and processing methods. Although the number of mills has increased, much of the processing still depends on very small scale and localized cottage industries and households.

These commodities are collected from the grading stations and moved southward for export by rail or road transport. Some are transported along the River Niger and exported through the delta ports. The development of these transport modes and their impact on the economy are discussed below.

2.3 Historical Development of the Transportation Modes

2.3.1 Inland Waterways and Ports

At first the European traders who travelled to Nigeria were content to operate solely along the coast through agents. By the end of the 19th Century they started to push their direct trading operations inland through the vast network of creeks, the River Niger and its major tributary the River Benue. Figure 5 shows the major features of inland waterway and the major seaports in Nigeria. Approximately 1,440 km (900 miles) of the river Niger and 960 km (600 miles) of the river Benue lie within Nigeria.

These major rivers do not serve the major population centres and, in addition suffer from other serious limitations. Their water levels vary greatly between wet and dry seasons limiting navigation to a few weeks a year on the river Benue and to 8 months a year on the river Niger below its confluence with the Benue. Another major limitation is the inability of ocean-going vessels to carry loads upstream through the delta ports due to progressive silting of the several entrances from the sea.

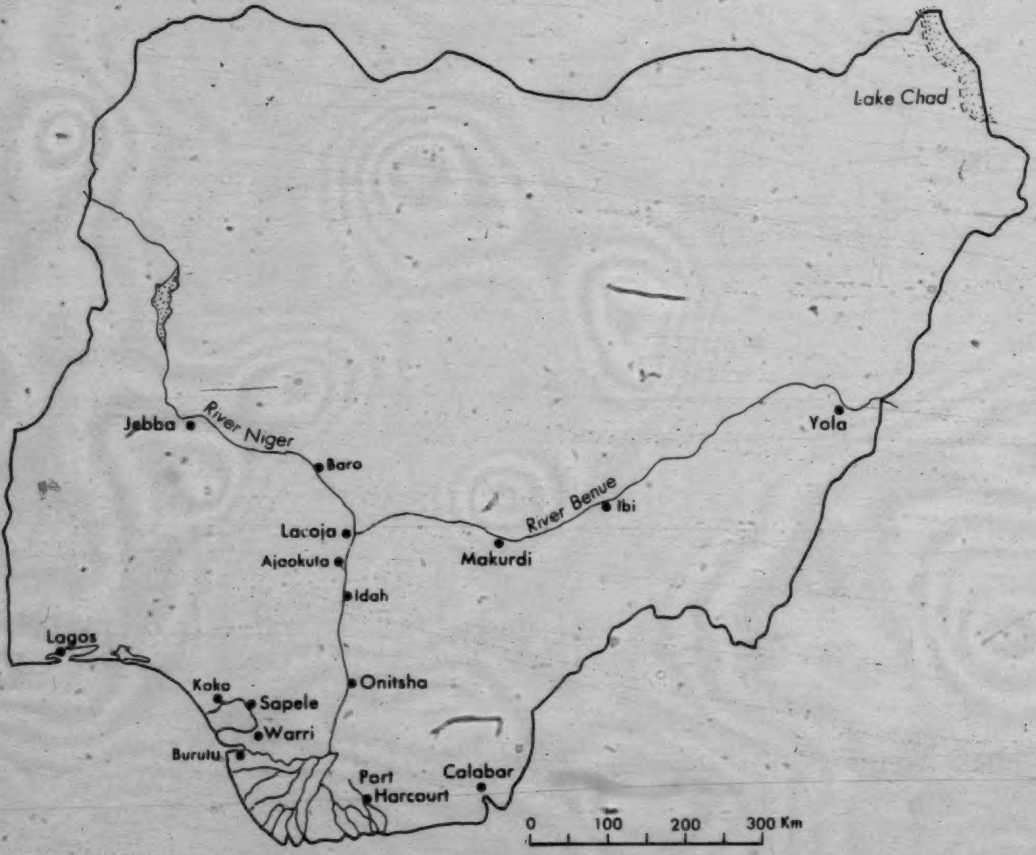

Lake Chad
Jebba
River Niger
Baro
Yola
River Benue
Ibi
Lacoja
Ajaokuta
Makurdi
Idah
Lagos
Onitsha
Koko
Sapele
Warri
Burutu
Port
Harcourt
Calabar
0
100
200
300 Km

FIGURE 5 INLAND WATERWAYS AND MAJOR SEAPORTS

46

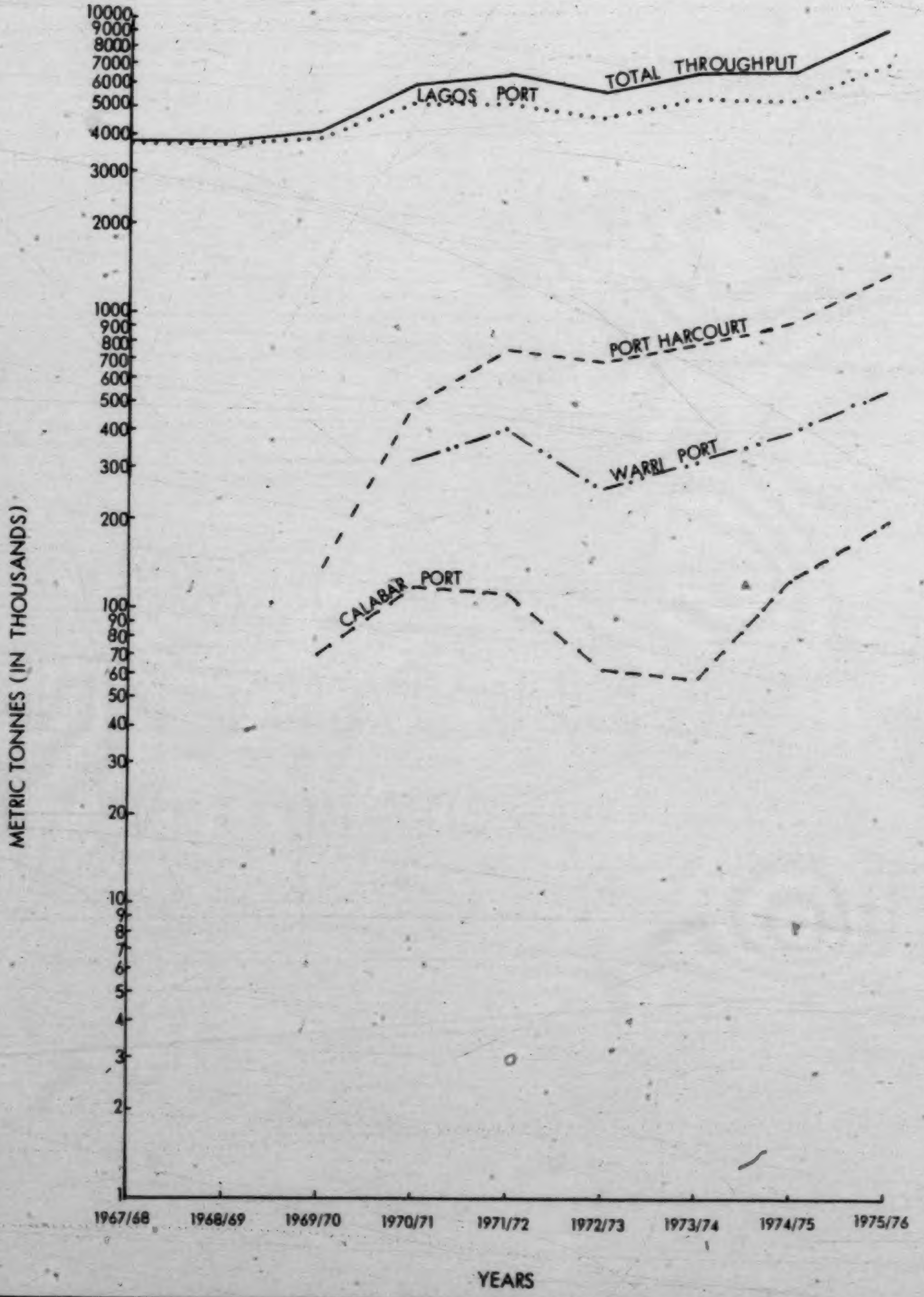
7

Major projects already undertaken to improve navigation are the Escarvos Bar Project on the coast and the Kainji Dam, intended to make it possible for modern vessels to navigate beyond Jebba. The fleets of river craft and barges operating on these rivers are based on the Niger delta ports of Warri and Burutu and the bulk of their traffic is for export or import via these ports. Other important river ports are Sapele, Onitsha, Ajaokuta, Idah and Baro, which is a rail-river transhipment center. The major seaports are Lagos, Port Harcourt, Calabar and the Delta port complex (i.e. Warri, Sapele, Koko and Burutu).

Figure 6 shows the amount of cargo throughput at the major Nigerian ports between 1966 and 1976. The quantities of cocoa and palm kernels shipped through the ports in 1976/77 were employed in the analysis. Generally, most Nigerian ports lack adequate port facilities and are deficient in specialized berths but have excess capacity in conventional berths. Consequently, most of these ports are congested in many respects. Lagos is the major port and suffered serious congestion problems between 1974 and 1977.

Before the Nigerian civil war (1967-1970), over 300,000 tons of freight were transported annually by inland waterways. Several private companies handled nearly all the traffic by modern craft on these rivers. By 1966, the Niger River Transport Company accounted for 66% of the total river ton-miles, while John Holts Transport Company handled 22% and the Niger Benue Transport Company handled 8% of total

FIGURE 6. CARGO THROUGHPUT OF THE MAJOR NIGERIAN PORTS



Source: Statistics Unit. , Nigerian Ports Authority, Lagos, Nigeria.

river tonne/kilometers. The civil war terminated the activities of the first two companies and reduced that of the third company considerably. In 1972, however, the Central Water Transportation Company (CWTC) with shares held by six Federal States was formed. This company was taken over by the Federal government in 1975 and now handles all the traffic by modern vessels on these rivers. Unfortunately, the tonnages transported in recent years are still less than 10% of the pre-war totals, despite the exceedingly low rates of 2.3 kobo per tonne/kilometer. This may partly be explained by the slow recovery of the agricultural economy of the areas along the river banks affected by the civil war (1967-1970) and partly by the Sahelian drought (1972-1974) which resulted in a sharp decrease in the water level.

In order to avert the continuing trend of port congestion, an ambitious port development programme was planned to take place during the current Third National Development Plan. This includes the plans for the expansion of berths at Apapa, Warri, Calabar, Port Harcourt and Koko, as well as the construction of new berths at Tin Can Island, Lagos. There are also plans to improve navigation on the inland waterways by dredging the rivers and providing navigation aids. High hopes of viable river traffic may depend on traffic to be generated by the proposed Ajaokota iron and steel complex and other major industrial undertakings planned for the current Development Plan period.

2.3.2 The Nigerian Railway System

Early reliance on the rivers and creeks as the chief means of transport shifted to the railway as soon as rail transportation became available. Figure 7 illustrates the major landmarks that are associated with the development of the Nigerian railway network. The railway was begun in 1898 with the construction of a line extending in a north-easterly direction from Lagos. It reached Ibadan in 1901 and Jebba on the river Niger in 1909. At Jebba, a bridge was completed in 1915, the first man-made structure over the river Niger. The bridge permitted the linking of the Lagos-Jebba line with the Kano-Baro line which had earlier been completed in 1911.

Subsequently, branch lines were built from Zaria to Kaura Namoda, Kano to Nguru and Iffo to Idogo. The Bauchi Light Railway line between Zaria and Jos was opened in 1912 primarily for the shipment of tin. Another rail line between Port Harcourt and Enugu was completed in 1916 and later extended to Jos and Kaduna, thus linking the eastern and western railway lines. The Bauchi Light Railway was closed for economic reasons in 1957, but another rail extension from Jos to Maiduguri in the north-east was completed in 1964. In 1966, a branch line from the Alesa Eleme Oil Refinery to Elelenwa on the Port Harcourt-Enugu line was completed.

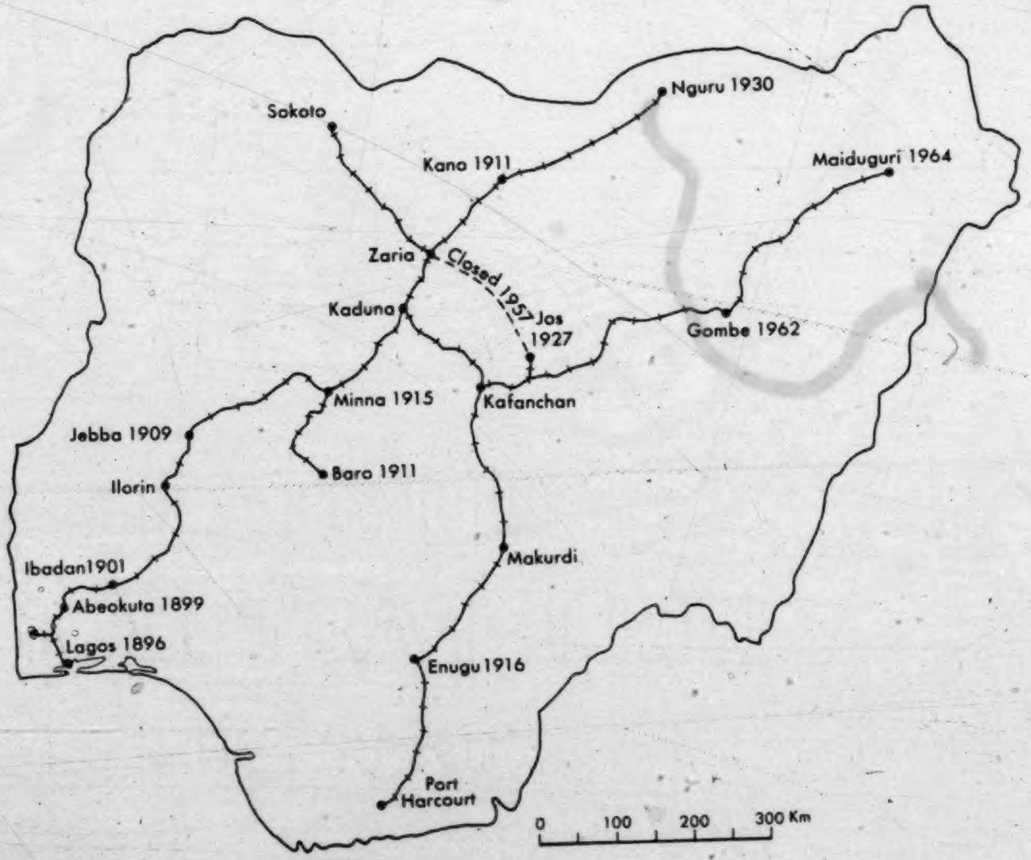

Sokoto
Nguru 1930
Kano 1911
Maiduguri 1964
Zaria
Closed 1957
Kaduna
Jos
1927
Gombe 1962
Minna 1915
Kafanchan
Jebba 1909
Baro 1911
Ilorin
Makurdi
Ibadan1901
Abeokuta 1899
Lagos 1896
Enugu 1916
Port
Harcourt
0
100
200
300 Km

FIGURE 7 HISTORICAL DEVELOPMENT OF THE NIGERIAN RAILWAYS

The present railway network consists of 3,505 route kilometers with a line of 1.067 meter gauge. This network connects the major ports of Lagos and Port Harcourt with the major urban centers in the country. The maximum permissible speed is only 64 kilometers per hour and the carrying capacity is barely 800 tonnes per train with a maximum axle load of 13.5 tonnes.

The railway made possible the development of the northern parts of Nigeria for agricultural exports. Unfortunately, there has been a continued decline in the performance of the railway and, since 1960, the deficit in its operating account has been increasing. This decline can be attributed partly to increased competition from road transport and partly to deterioration of the railway's transport services. It can also be partly attributed to a general decline in those traditional export commodities which used to form a significant portion of the freight handled by the rail, in particular, groundnuts.

In order to effect a drastic modernization of the railway system the Federal government plans to construct a standard 1.535 meter gauge railway system to replace the existing line. The new line will be built on an entirely new road-bed, with an alignment that will eliminate existing steep gradients and sharp curves. The new system will permit average speeds of up to 160 kilometers per hour and is expected to be more reliable, safe and efficient. Also, two new lines from Ashaka to Bauchi cement Factory and from

Oturkpo to Ajaokouta will be constructed during the current Third National Development Plan period.

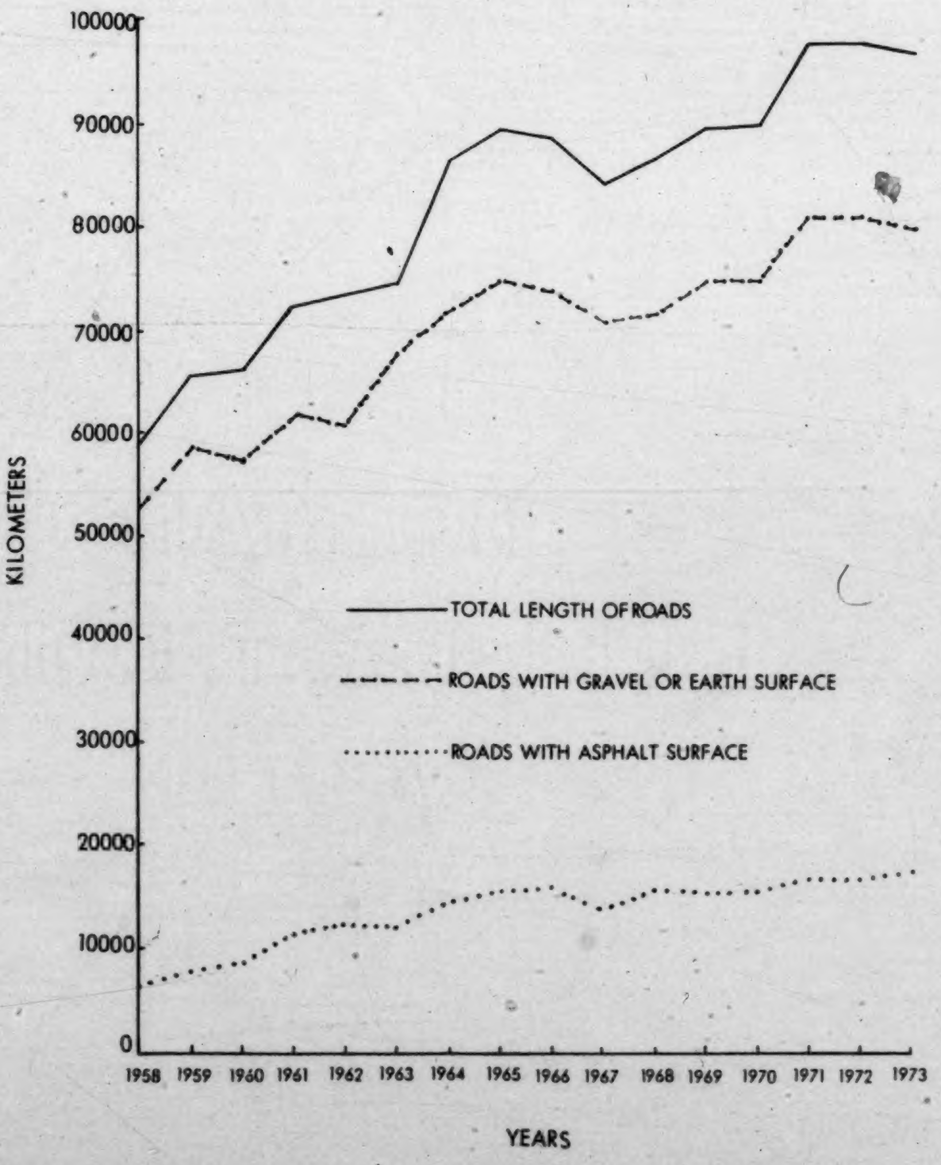
2.3.3 Road Transport Network

The history of road transport in Nigeria dates back to the first decade of the 20th century, when the existing bush paths were widened into motorable routes. These routes were intended to reduce the strain of providing porters for the colonial officials and to link nearest centers with major railway stations for the evacuation of local export products.

In southern Nigeria, the presence of tse-tse-fly was unfavourable for animals. Therefore, road transport development jumped from the headloading stage into the modern vehicle stage without evolving through the stage of animal-drawn carts as in the northern parts of the country. Roads were not widely developed until the advent of motor vehicles in the 1920's and 1930's, however. In fact, it was only after World War II that the country came to be served by an extensive network of roads.

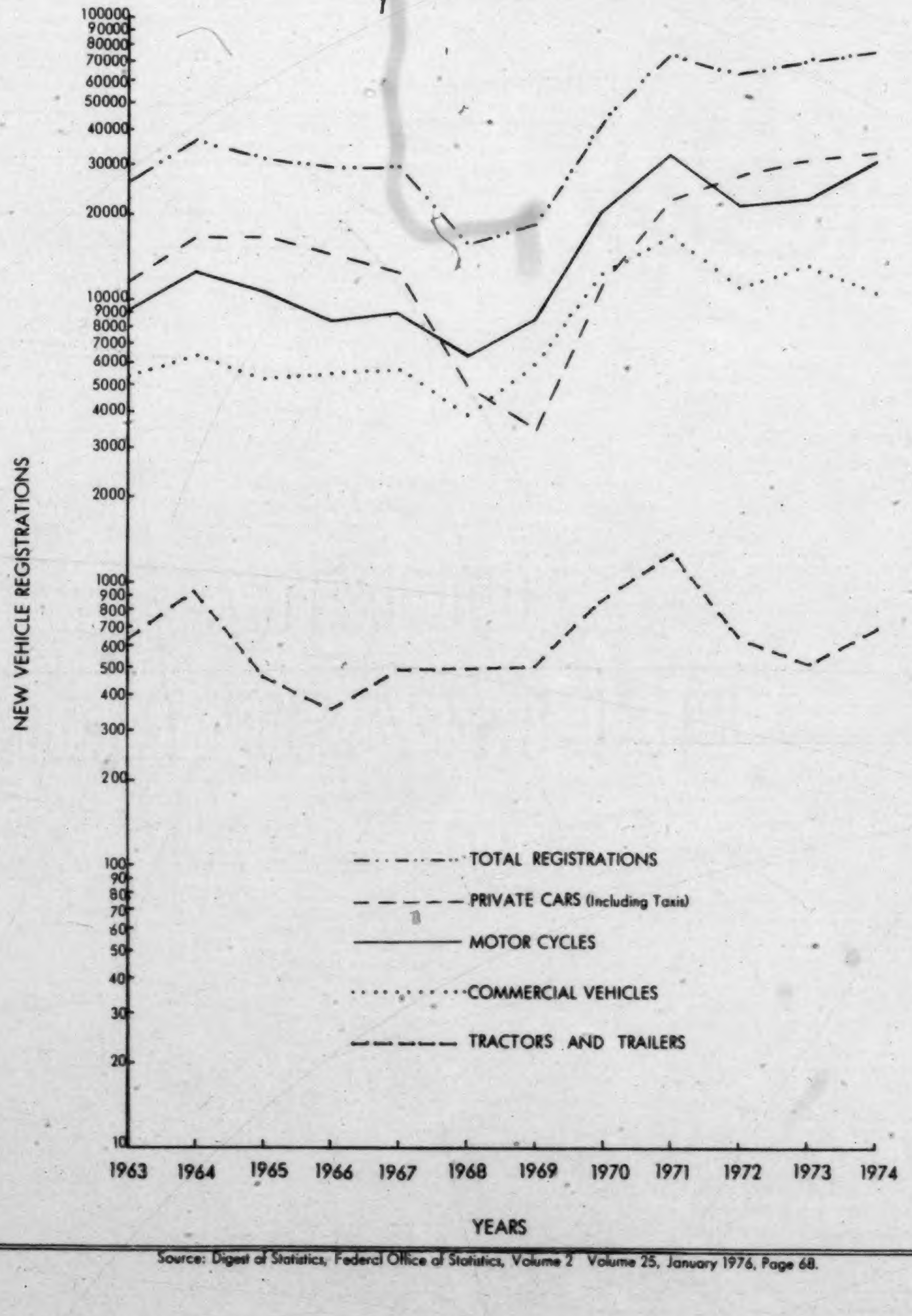
The present road system, while far below the standards of advanced countries (especially in parts of the rural areas), is relatively good compared to systems in other developing countries. Figure 8 shows that since 1958 the total length of roads in the country as well as the proportion that has asphalt surface has increased steadily. Figure 9 also indicates a tremendous increase in the number

FIGURE 8. LENGTH OF ROADS IN NIGERIA (1958 - 1973)



Source: Digest of Statistics, Federal Office of Statistics, Volume 2 Volume 25, January 1976, Page 67.

FIGURE 9. NEW REGISTRATIONS OF ROAD VEHICLES IN NIGERIA(1963 - 1974).



Source: Digest of Statistics, Federcl Office of Statistics, Volume 2 Volume 25, January 1976, Page 68.

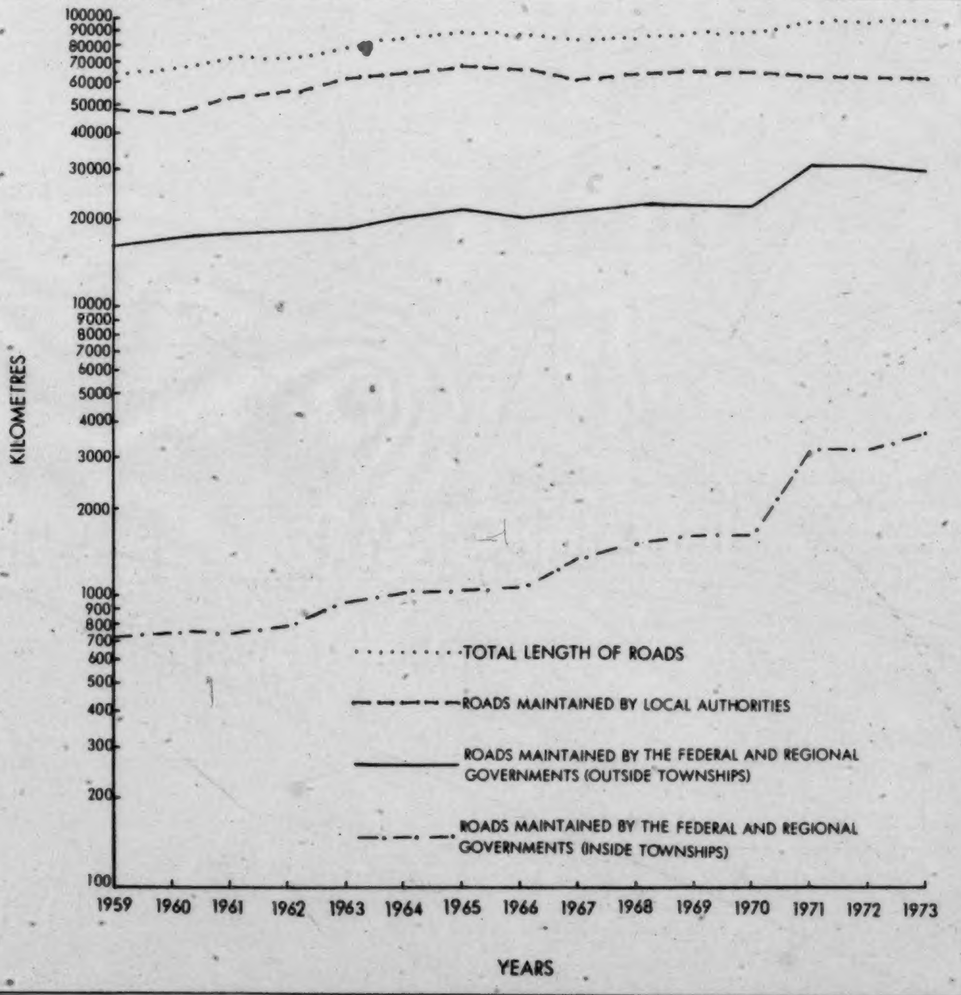
of new vehicle registrations in Nigeria since 1953. Practically speaking, all parts of the country are now linked by some form of road although the concentration is heavier in the south than in the less densely populated north. More roads have been constructed in the north in recent years, however.

In 1926, the road system of Nigeria was classified into three major groups. Under the system, Federal Trunk A roads linking the Federal capital with regional capitals and other large towns were to be constructed and maintained by the Federal government. Regional Trunk B roads connecting provincial or divisional headquarters with other large towns were to be maintained by the Regional or State governments. Provincial Trunk C roads connecting the areas between the other road systems were to be maintained by the local government. Figure 10 shows the length of roads maintained by various authorities in the country.

This system of allocation is not equitable because local governments, which are least able to construct and maintain roads in terms of funds and personnel, had the largest responsibility while the Federal government which is more affluent had the least responsibility. The Kampsax Report on Highway Maintainance (1972) attributed the generally poor standards of construction and maintenance of most roads to this imbalance of responsibilities in the road transport sub-sector.

In 1975, the Federal government took over a total of

FIGURE 10 LENGTH OF ROADS MAINTAINED BY VARIOUS AUTHORITIES IN NIGERIA (1959 -1973)



Source: Digest of Statistics, Federal Office of Statistics, Volume 2 Volume 25, January 1976, Page 67.

16,000 kilometers of State roads and added this to the existing 15,000 kilomters of Federal roads. Thus, the Federal government became responsible for 31,000 kilometers of road or one third of the total national road network (Figure 11). This has enabled the State governments to take over many feeder roads from the local governments and consequently, under the current development plan, the State government's allocation to road development is quite substantial.

2.3.4 The Role of Transportation in the Marketing of Export Commodities

Table 2 illustrates the relative importance of rail, road and waterways in handling Nigeria's export and import traffic in 1975/76. Over 92% of import traffic and 75% of export freight in all the major seaports was handled by road transport. The share by rail transport is quite low. Figure 12 illustrates that the share of export commodities in the railway goods traffic has dropped from a peak of 53 percent in 1968/69 to 13 percent in 1973/74. Unfortunately, there is no breakdown of the figures by commodity.

Although inland waterways play a minor role as feeder routes to the seaports, their traffic is heavier for exports than for imports. The quantity of export commodities handled by the Central Water Transportation Company (CWCT) shows a

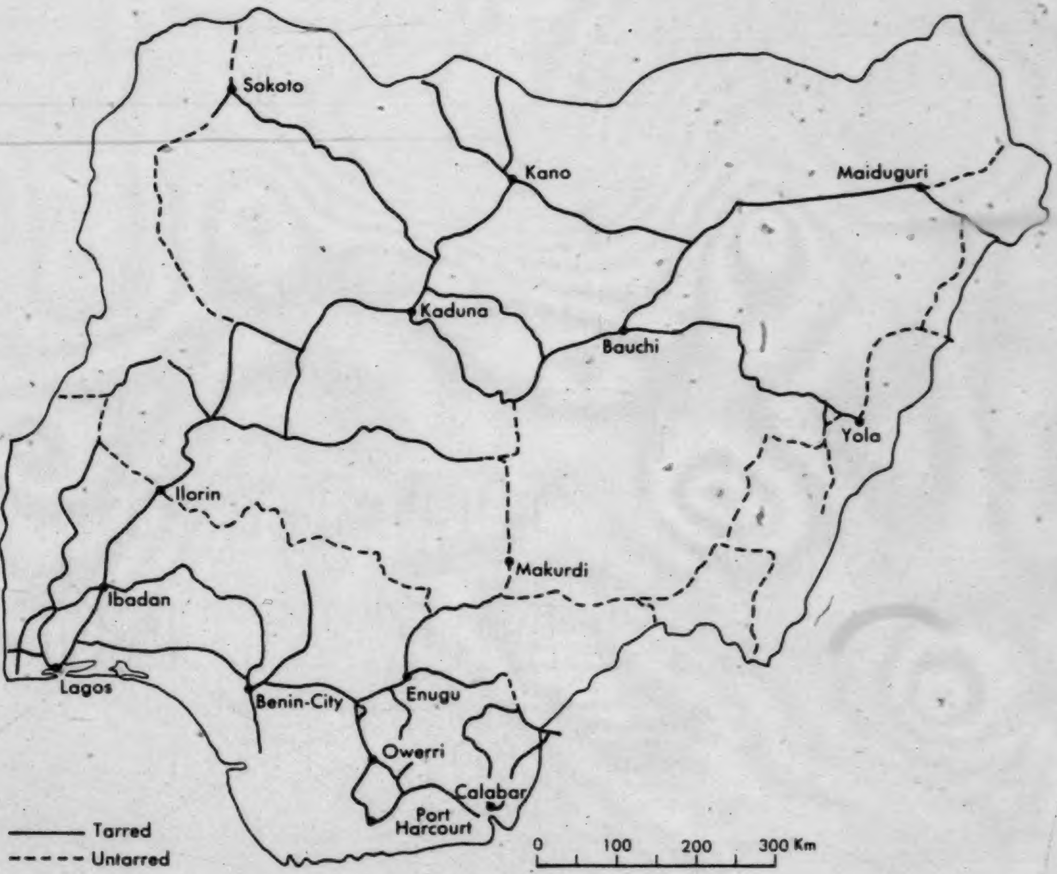

Sokoto
Kano
Maiduguri
Kaduna
Bauchi
Yola
Ilorin
Makurdi
Ibadan
Lagos
Benin-City
Enugu
Owerri
Calabar
Port Harcourt
Tarred
Untarred
0
100
200
300 Km

FIGURE 11 POST 1975 TRUNK 'A' ROAD SYSTEM

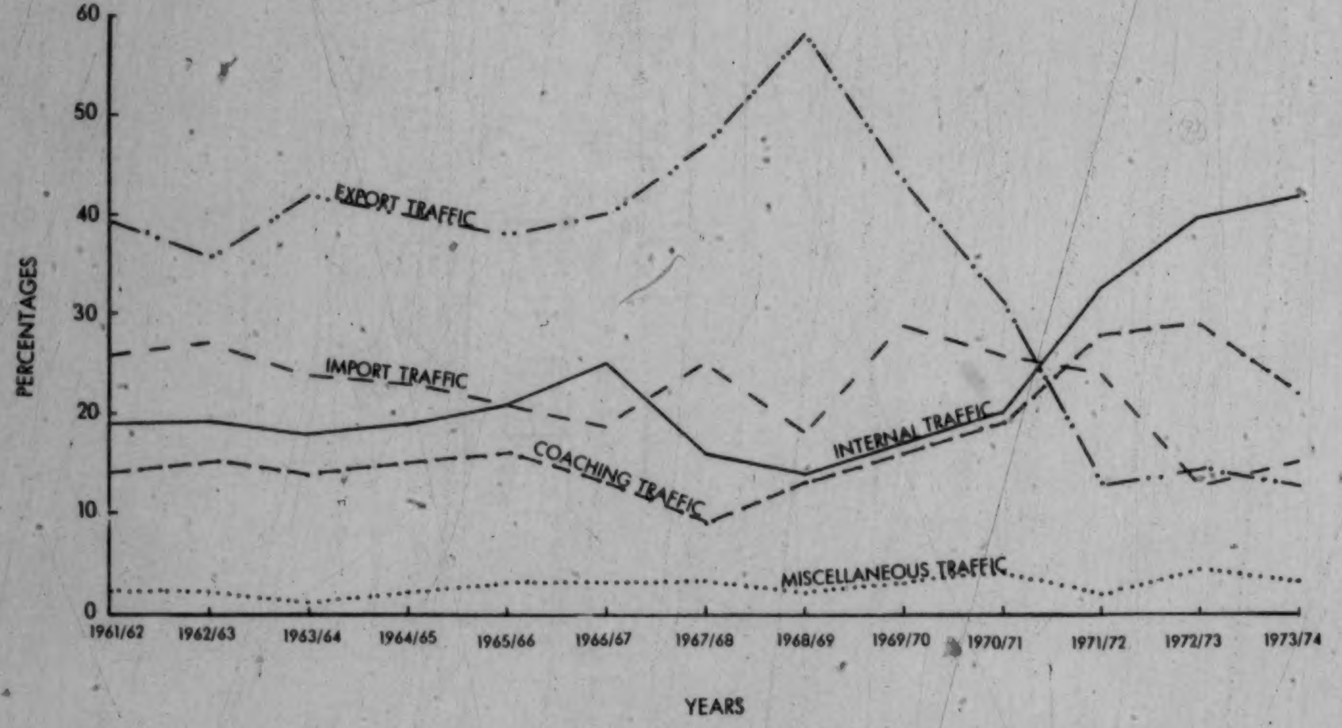
TABLE 2. ROAD, RAIL AND LIGHTER TRAFFIC THROUGH THE MAJOR SEAPORTS IN 1975/76 (In 1,000 Tonnes)

MAJOR PORTS	ROAD		RAIL		LIGHTER	
	IMPORT	EXPORT	IMPORT	EXPORT	IMPORT	EXPORT
LAGOS	3,025	347	209	10	26	*
PORT HARCOURT	1,016	67	96	41	*	*
CALABAR	53	26	*	*	9	*
KOKO	151	*	*	*	*	*
WARRI	360	5	*	*	11	135
TOTAL	4,605	445	305	51	46	135
% TOTAL	92.9	75.5	6.2	8.1	2.9	21.0

N. B. * Indicates Negligible.

Source : Nigerian Ports Authority (NPA) 21st Annual Report for the Year ending 31st March, 1976.

FIGURE 12 . PERCENTAGE DISTRIBUTION OF REVENUE BY TYPES OF TRAFFIC ON THE NIGERIAN RAILWAY SYSTEM (1961 - 1974)



Source: Annual Reports (1961/62 to 1973/74), Nigerian Railway Corporation, Lagos, Nigeria.

fluctuating trend. Table 3 shows that palm kernels and beniseed are the most important export commodities handled by the company. In 1975/76, there was no transportation by the company because the tugs were non-operational.

It is not surprising that with the marked increase in the development of roads and the simultaneous operational and organisational difficulties being experienced by the railway and inland waterway systems, the long-distance freight transport pattern in Nigeria is dominated by road transport. Figure 13 shows the development of this trend at the port of Lagos.

Hay (1969, 1971) studied the economic structure of road transport industry in Nigeria. He attributed the greater advantage of the road transport industry in the country to the organizational ability rather than areal flexibility usually attributed to roads. This advantage enables the industry to pick up profitable traffic from the railway, to vary rates according to seasonal fluctuations in demand and to keep in close contact with the traders who constitute the greatest part of the demand.

There are numerous carrier organizations that provide regular services from Lagos and other seaports to all parts of the country. They operate mainly 10-tonne and 25-tonne capacity trucks which carry freight directly, without re-loading from the shipping depot to the consignee. Speed, door-to-door delivery and greater flexibility are the major

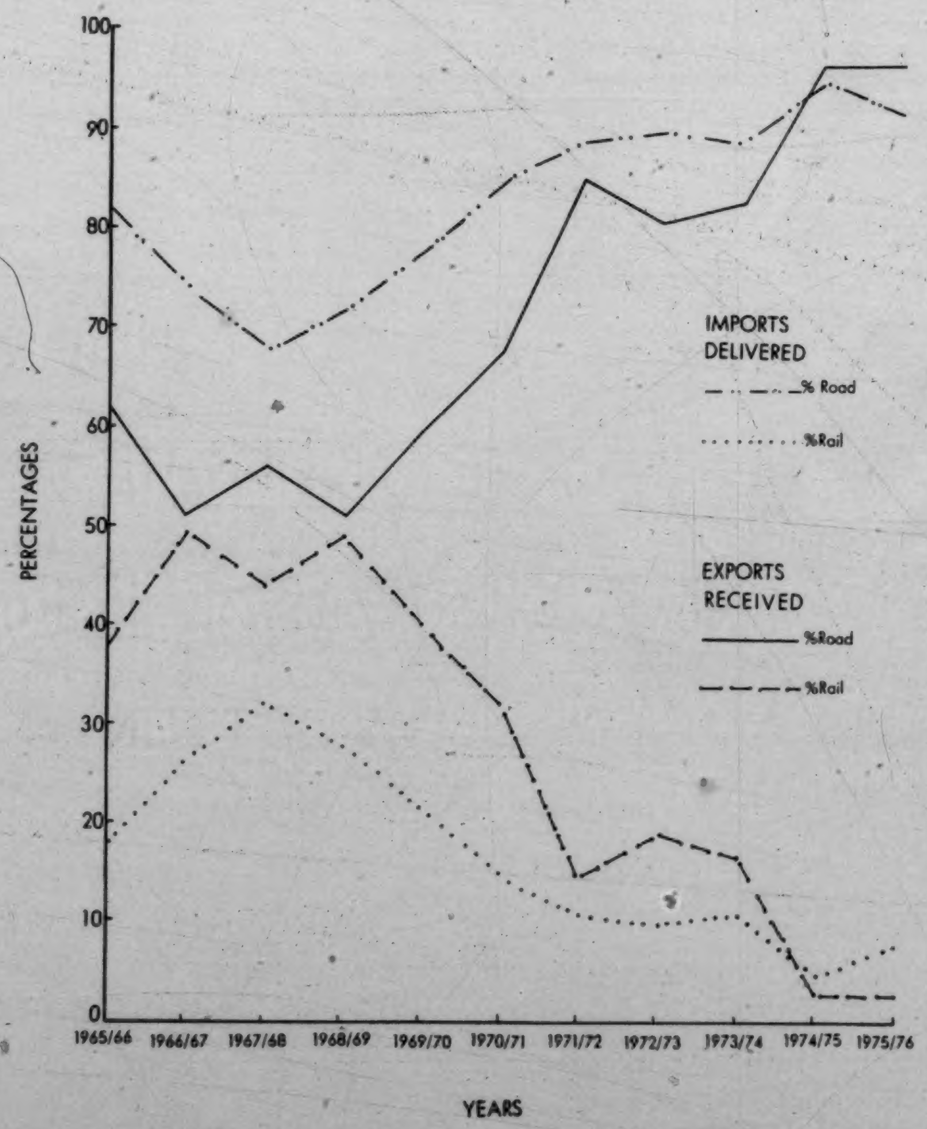
TABLE 3. CENTRAL WATER TRANSPORTATION COMPANY (CWCT) TRAFFIC STATISTICS SUMMARY (In Tonnes)

COMMODITY	1971/72	1972/73	1973/74	1974/75	1976/77
PALM KERNELS	3,461	10,396	2,046	5,043	4,104
SAW TIMBER	*	900	*	*	*
CHEMICALS	*	514	926	870	*
PIPES	*	52	*	1,200	*
TUBINGS	*	*	43	*	*
LOGS	*	*	*	1,191	*
GROUNDNUTS	*	*	6,538	*	*
BENISEED	*	*	1,490	3,395	1,711
TOTAL	3,461	11,862	11,043	11,699	5,815

N. B. * Indicates Negligible.

Source : Statistics Section, C. W. C. T., Onitsha, Nigeria.

FIGURE 13. PERCENTAGE DISTRIBUTION OF TOTAL TONNAGES HANDLED BY ROAD AND RAIL AT LAGOS (APAPA) QUAYS (1965 - 1976)



Source: Statistics Unit. , Nigerian Ports Authority, Lagos, Nigeria.

advantages of road transport. These may be reduced considerably in future, due to heavy growth in freight traffic and subsequently congested roads and serious losses through accidents. Therefore, the complex task of programming the storage and regular movement of export commodities from upcountry to the ports requires close cooperation between road, railway and inland waterway transportation systems.

2.4 The Marketing Board System in Nigeria

2.4.1 Historical Development of the Marketing Boards

Buying and marketing of export commodities in Nigeria is done by Government Marketing Boards. The establishment of these boards originated from the World War II arrangements for the marketing of the West African primary produce in the United Kingdom. After the cessation of hostilities four Nigerian Commodity Marketing Boards for cocoa, oil palm produce, groundnut and cotton, emerged. The Nigerian Cocoa Marketing Board was formed in 1947, while the others were formed in 1949.

The major principles adopted for the post war marketing of export commodities were set out in the Colonial Office White Paper and were subsequently adopted in the Nigerian Cocoa Marketing Board Ordinance (No. 33 of 1947). The Board was established in order,

> "To secure the most favourable arrangement for the purchase, grading, export and marketing of Nigerian cocoa, and to assist in the development by all possible means of the cocoa industry of Nigeria for the benefit and prosperity of producers." [1]

When the Marketing Boards for the other commodities were established they were given similar responsibilities. They were expected to stabilize producer prices, organize marketing, shipment and overseas sales of these commodities. In addition to encouraging economic development, they were expected to help in appropriate ways to finance and promote research for increasing production and improving the quality of the crops.

With the Nigerian constitutional revisions in 1954 which involved the devolution of considerable powers to the regional governments, there came a reorganisation of the marketing board structure. Instead of being organized on a nation-wide commodity basis, they were organised on a regional cross-commodity basis. This meant that each Regional Marketing Board handled all the relevant exportable surplus in its region of jurisdiction while the Nigerian Produce Marketing Company handled overseas marketing of the export commodities. The same cross-commodity structure was continued under the subsequent administrative state systems.

The performance of the Marketing Boards in Nigeria has been severly criticised. Local processors complained that the Nigerian Produce Marketing Company sold commodities to them at the world market price whereas they could buy at a cheaper price directly from the farmers. The cross-commodity structure did not encourage specialization along commodity lines. In 1971, the Nigerian Institute of Social and Economic Research organized a conference to discuss the Marketing Board system in Nigeria. From the proceedings of the conference, it was noted that although the Boards performed their marketing functions efficiently, they neglected the interest of local producers. Several modifications that would enable the system to operate to the advantage of the country's economy were recommended. Subsequently, the Marketing Board System was revised in April 1977 by the promulgation of the Commodity Boards Decree No. 29 by the Federal Military Government.

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[1] The Nigerian Cocoa Marketing Board Ordinance (No. 33) of 1947, Section (16).

In accordance with the provisions of the decree, seven Commodity Marketing Boards were established, the details of which are shown in Table 4. The new system permits domestic industries to purchase export commodities directly from the farmers. This policy was aimed at enabling the farmers who produce these commodities to earn maximum income on the portion of their products that enter the domestic market. It was also aimed at encouraging local processing.

Each Commodity Board is expected to secure the most favourable arrangements for the purchase of the relevant commodities in any part of the country. It is also responsible for the sale of these commodities

TABLE 4. EXPORT COMMODITY BOARDS IN NIGERIA BY 1977

COMMODITY BOARD	COMMODITIES HANDLED	HEADQUARTERS
Nigerian Cocoa Board	Cocoa, Coffee and Tea	Ibadan
Nigerian Groundnut Board	Groundnuts, Soyabeans, Ginger, Beniseed and Sheanuts	Kano
Nigerian Cotton Board	Cotton Seed ,Cotton Lint, and Kenaf	Funtua
Nigerian Palm Produce Board	Palm Oil, Palm Kernel and Copra	Calabar
Nigerian Rubber Board	Rubber	Benin
Nigerian Grain Board	Guinea Corn, Millet,Rice Maize, Wheat and Beans	Minna
Nigerian Tuber and Root Crops Board	Yams and Cassava	Makurdi

Source : Commodity Boards Decree, Supplement to the Official Gazette, No. 18, Vol. 64, 21st April, 1977.

to meet domestic requirement and arranging for the evacuation of any surplus intended for export. Thus, the services of the Nigerian Produce Marketing Company Limited became redundant and it was therefore dissolved by the decree.

2.4.2 Marketing System for Export Crops in Nigeria

Since the production and processing of agricultural export commodities in Nigeria are widely dispersed throughout the country, their evacuation to the ports takes place in several stages. This explains why it is necessary to make use of the licenced buying agents to collect the commodities from the dispersed producers, and bulk the collections into bigger lots which are then sent to the ports or to designated warehouses of the Marketing Boards. Thus, a pyramidal structure for the marketing of export commodities in Nigeria has developed (Figure.14).

At the apex of the pyramidal structure was the Nigerian Produce Marketing Company (NPMC) which linked Regional/State Marketing Boards with the European and later American markets. With the establishment of the Commodity Boards in April 1977, the NPMC was dissolved and each Commodity Board took over both its functions of export marketing and also the functions of the former State Commodity Boards for specific commodities. The position of the licenced buying agents and the local produce collectors in the pyramidal structure remain unchanged.

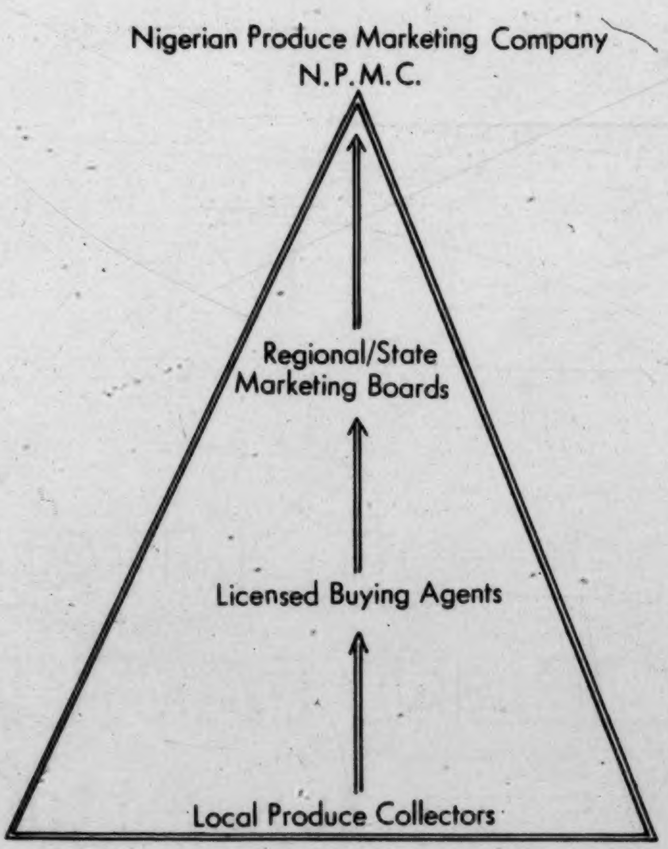
Nigerian Produce Marketing Company
N.P.M.C.
Regional/State
Marketing Boards
Licensed Buying Agents
Local Produce Collectors

FIGURE 14 THE PYRAMIDAL STRUCTURE OF THE MARKETING SYSTEM FOR EXPORT COMMODITIES IN NIGERIA

The small scale producers take their produce to the nearest gazetted grading station where the staff of the Produce Inspection Division of the Ministry of Agriculture and Natural Resources inspect and grade the produce according to the quality desired for export. After this, the licenced buying agents buy the graded produce from the farmers at the current producer prices for each commodity. A buying allowance is paid to the licenced buying agents for their services. This allowance is set to enable them to make a small profit after paying commission to their sub-buyers, since it is absolutely impossible for the agents to visit each station every day for direct purchases.

When the small scale producers are unable to take their bulky commodities to the grading stations due to inadequate means of transport, bad roads or other reasons, the local produce collectors usually employed by the licenced buying agents visit the production units, village markets or households in the villages to make purchases. This is known as 'bush collection' and the Boards pay the licenced buying agent a stipulated Buying Allowance in order to cover his expenses. The bush collection stage makes it possible to evacuate produce that would otherwise have been wasted. It usually involves small quantities and relatively short distances and is not considered in this study.

The present study is concerned with the transport differential rate of the Commodity Boards which applies to the movement from the grading stations to the ports and involves larger quantities of the commodities and longer distances. This is usually done by the licensed buying agents who are paid a fixed rate per tonne/kilometer for the quantity of commodity transported.

2.4.3 Transport Allowance of the Marketing Boards

The prices paid to the producers or farmer's of these commodities are related to the world market prices and to the previous year's trading results. They are usually announced at the beginning of each marketing season. This producer price and the buying allowance are determined at the national level by a Committee of the Price Fixing Authority. The setting of the transport allowance, however, is the responsibility of the Commodity Boards.

There is the general impression that there is a common tendency to overstate the transport allowance and thus provide opportunities for inefficiencies in the system. The licenced buying agents receive the stipulated road transport allowance regardless of the method actually employed for shipping the commodities. It is possible that they may be spending less than the approved allowance.

Most of the licensed buying agents are also sales agents for many commercial vehicles sold in Nigeria, and this gives them a special incentive to encourage road transport. The buying agents often own trading companies that handle a wide variety of imported goods and distribute them throughout the country. This provides their lorries with return loads from the seaports. This type of situation gives rise to conflicting interests that may result in inefficient utilization of the transportation system.

2.4.4 Relevance of the Research

Early studies of transportation in Nigeria such as Robinson et al (1961) and Economic Associates of London (1967) did not pay enough attention to the problems of evacuating the major export crops of Nigeria. A later study by Kriesel (1968) considered groundnut evacuation, but only in a general marketing context. The first specific reference to transport optimization in Nigeria was in a report by NEDECO (1970). The NEDECO study did not consider the Marketing Boards as the unit of analysis but was concerned with overall economic planning. Osayimwese (1971,1973) applied linear programming to the study of the transportation of groundnuts in Nigeria. The minimum cost of shipping groundnuts from a given region to each major port by road and railway was computed in order to obtain the optimal shipping pattern, which was then compared with the actual traffic through the ports. He was concerned with the capacity of the ports to handle the groundnut traffic. Ige (1975) applied the transportation model of linear programming to optimizing the pattern of distribution of cement in Nigeria.

There has not yet been any study of the present pattern of transporting export commodities within the country with a view to assessing the overall efficiency of shipments. The present pattern of shipments indicates that the Commodity Boards do not assume the responsibility for determining and enforcing the use of the most economical means of transporting these commodities by the licensed buying agents. Yet, the competitiveness of Nigeria's export commodities abroad depends largely on the degree to which inland shipping costs , can be reduced.

Nigeria's transportation objectives were spelled out for the first time in 1965 in a Government White Paper. The Paper advocated that the country must ensure that her

> "transport services are fast, dependable, and up-to-date as well as economical. These objectives can be achieved only if each agency of transport operates in the most efficient way and if all are co-ordinated with each other in the most effective manner". [2]

Although these objectives are still valid, this policy statement has not been revised since 1965 in order to incorporate many changes that have taken place. This is necessary and may help to justify some of the heavy investments in transportation under the Third National Development Plan.

The government has made statements which give impressions of concern but no clear evidence exists to prove that firm measures have been taken beyond declaration of intentions. There is therefore, an urgent need to investigate the consequences of improper and unregulated use of transport facilities in the country. In this study, the present pattern of shipping cocoa and palm kernels are investigated in order to identify the inefficiencies in the shipping pattern. The research aims at obtaining a quantitative impression of what the excess or insufficient demand for these commodities at the ports are costing the Commodity Boards in terms of inland shipping costs. The optimal pattern may indicate those areas which are best located for producing these commodities if the only factor taken into consideration is the shipping bill of the Boards. In order to reduce these shipping bills, there should be a firm commitment to the least costly modes of transport and to the optimal allocation of traffic to the existing routes. The study identifies these optimal routes of shipment when link capacities are not taken into consideration.

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[2] Federal Republic of Nigeria, Statement of Policy on Transport, Sessional Paper No. 1, Printing Division, Fedreal Ministry of Information, Lagos, 1965.

In the long run, if a more rational allocation can be achieved, the savings resulting from the more efficient use of transport facilities will mean higher producer allowance for farmers, larger surpluses for development programs and for improving infrastructure such as road networks in producing areas. All these will help to promote economic development.

The major limitation of the research is that there are no data on actual shipments to the ports against which the optimal patterns obtained from the study can be compared. The Commodity Boards could not provide any reliable data on the actual shipments from the grading stations to the ports. Another limitation is that since only cocoa and palm kernels which are grown only in the southern part of Nigeria are considered, the results and recommendations do not apply to the whole country. However, it provides an insight into the basic issues involved.

3. Chapter Three LITERATURE REVIEW

3.1 Introduction

This chapter presents a survey of the literature on the 'Transportation Problem' as an introduction to the formal model that was used in this study. The Transportation Problem is one of the most important linear programming problems for two main reasons. First, it is not simply a single problem but represents a class of problems covering a variety of applications. It is of special relevance to geographers who often employ the model for the minimization of the adverse effects of space. In addition, it has been studied for a longer period than any other class of linear programming problems. For these reasons, the literature on the transportation problem is vast, varied, and sometimes confusing.

This chapter presents a discussion of the objective function, the associated constraints and a number of solution algorithms for solving the Transportation Problem. In the discussion, a distinction is made between linear and non-linear transportation models. Generally, the static or deterministic formulation of the Transportation Problem which may involve optimization for a single time period is linear. On the other hand, the Stochastic Transportation Problem in which at least one of the parameters is a random variable and optimization is for several time periods, is non-linear. In such problems, the present period's solution depends crucially on the inventory at the end of the previous period. However, since this study is concerned wth developing short-run models for 1976/77, stochastic or dynamic problems are not discussed. Linearity or non-linearity are therefore discussed only with regard to whether the objective function is linear or not.

3.2 Methods and Applications of the Transportation Problem of Linear Programming

3.2.1 The Linear Transportation Problem of Linear Programming

3.2.1.1 The Classical Transportation Problem

The Classical Transportation Problem (CTP) was first formulated and solved by Hitchcock (1941) and later by Koopmans (1949). Berge (1962) however indicated that Monge, a French mathematician, had actually formulated the transportation problem in 1781. The Transportation Problem involves the distribution of a homogeneous commodity from several spatially separated sources to several demand points in such a way as to minimize total shipping costs. In the simple formulation of the Transportation Problem, it is assumed that every source is connected to every destination and that direct shipments from any source to any destination are feasible and more economical than shipments through other sources or destinations.

The Transportation Problem requires a demand curve which is perfectly inelastic. The total demand at J (DJ) and the supply at i (Si) are given. These availabilities and requirements are fixed since total input is equal to total output ($\sum Si = \sum Dj$). The cost of transporting any amount of the commodity is assumed to be directly proportional to the amount of the commodity transported.

The linear programming model provides the optimal pattern of shipments which may then be compared with the actual pattern in order to asses the efficiency of the existing pattern. The relationship between the optimal pattern of shipments obtained from the model and the existing pattern may have important theoretical and practical implications. For example, knowledge of the optimal pattern may indicate ways of reducing shipping costs in the present system. Also, in trying to explain why actual flows differ from the optimal flow pattern, the model may indicate where factors other than shipping costs determine the existing pattern of flows.

3.2.1.2 The Primal Problem

Nominally, the transportation problem determines those shipments, Xij, which minimize shipping costs while ensuring that the supply capacities of origins (Si, i=1,...,m) are not exceeded and that destination demands (Dj, j=1,...,n) are met. Mathematically, the transportation problem minimizes the objective function:

$$\text{MIN } Z = \sum_{i=1}^{m} \sum_{j=1}^{n} Tij\ Xij \qquad (1)$$

Subject to the constraints,

$$\sum_{j=1}^{n} Xij \leq Si \quad (i=1,\ldots.m) \qquad (2)$$

$$\sum_{i=1}^{m} Xij \geq Dj \quad (j=1,\ldots.n) \qquad (3)$$

$$Xij \geq 0 \quad \text{for all } i, j \qquad (4)$$

Where,

Xij is the amount of flow on link ij
Tij is the unit freight rate of shipping on link ij
m is the number of sources
n is the number of destinations

The objective function (1), minimizes the total transportation costs, constraint (2) ensures that the flow leaving source i to all destinations is less than or equal to the supply at i, constraint (3) that the total flow entering destination j from all sources is at least as great as the requirements at j, and constraint (4) is the standard non-negativity constraint of linear programming. It can be interpreted as indicating that no negative shipments are allowed in the system.

3.2.1.3 The Dual Problem

To every linear programming resource allocation problem, there corresponds a linear programming valuation problem which is called its dual. The minimum value of the primal problem is equal to the maximum value of the dual problem. The function of the dual is to maximize the value of products at the producing regions and also to maximize the income received for the products at the market or demand points. The optimum values of the dual are obtained when the pattern of shipments is optimal with respect to the minimum aggregate shipping cost. Thus, it provides a measure for estimating the relative differences in prices of goods at their sources and at the demand points among different production points and demand points.

The dual of the transportation problem is formulated as follows,

$$\text{MAX } Z' = \sum_{j=1}^{n} vjDj - \sum_{i=1}^{m} uiSi \tag{5}$$

Subject to the constraints,

$$vj - ui \leq Tij \qquad \begin{matrix} (i=1,\ldots\ldots,m) \\ (j=1,\ldots\ldots,n) \end{matrix} \tag{6}$$

And,

$$vj,\ ui \geq 0 \qquad \text{for all } i,\ j \tag{7}$$

These dual variables can be defined in the following way,

ui = The shadow price per unit on the production capacity for the commodity at the producing origin i (i=1,.....,m). This imputed f.o.b. price indicates the marginal value to the solution of an additional unit of capacity at origin i.

vj = The shadow price or rent per unit on the demand for the commodity at destination or consuming region j,(j=1,....n). This imputed delivered c.i.f. price indicates the marginal cost to the solution of an additional unit of demand at destination j.

Judge & Wallace (1958) demonstrated that the values of the shadow price at the origin ui (i=1,...,m) and the shadow price at the destination vj (j=1,...,n), measure the comparative advantage of surplus regions and demand regions, respectively. The dual variable ui results from the spatial competition among various suppliers of the commodity while vj is attributed to the demand points competing for the limited supplies of the commodity.

These ideal prices provided by the dual can be compared with the ideal or assumed price structure just as optimal shipments between origins and destinations can be compared with real shipments. Since no profit above transportation cost is allowed, the imputed value of the dual variables are those that will lead to the optimal solution if the principles of perfect competition hold. Thus, the optimal pattern of shipments and its dual price system together provide a complete description of perfect competitive equilibrium.

The constraint on the dual states that the value of the differential between the shadow price of one unit of a commodity at the destination and the shadow price of one unit of the same commodity at the origin cannot exceed the transport costs involved in making the shipments. Stevens (1960) presented an interpretation of the dual variables as location rents on a unit of capacity at i (ui), and as location rents on a unit of demand at j (vj). He proved the dual objective function to be consistent with a go[illegible] profit maximization of purely competitive traders and constraint (6) to be consistent with the definition of location rent.

The structure of rents depends on the existence of zero rent in one supply region, and if there is complete interconnection there need be only one such location. The furthest supply region supplying the consumers at j earns this zero rent. Closer supply regions earn differential location rents exactly equal to the amounts saved on transportation of the units of the commodity supplied by them as opposed to the units supplied by this furthest supply region. Also, when a region's capacity is fully utilized, the region has a rent which is greater than zero, if the regional capacity is not fully utilized the region receives zero rent.

Therefore, the relevant characteristics of the dual can be summarized as follows,

1. The best supply regions or firms earn zero rent such that when $vj - ui = Tij$, $Xij > 0$ and also when $vj - ui > Tij$, $Xij = 0$
2. Capacities fully utilized earn positive royalties while those that have some unutilized capacities earn zero royalties, such that, when $ui > 0$, $Ki = Xij$ and also when $ui < 0$, $Ki > Xij$, where Ki is the capacity at i.

Boventer (1961) and Abouchar (1967) demonstrated how the interrelationships between the dual variables of the transportation problem can be used as a key to locational planning. For example, in order to discourage the supply of a product from a certain region, the differential rent that the supplier must pay for having a locational advantage with respect to existing patterns of demand should be increased. Similarly, a reduction in the level of demand at a consuming region can be obtained by increasing the surcharge component of the product in that region to the advantage of other consuming regions. Ghosh (1965) applied the Transportation Model to the Indian cement industry and used the solution to the dual problem to illustrate how inter-regional flows of cement in India could be regulated. He indicated that if the primal problem has restrictions on productive capacity or any type of capacity, the solution to the dual problem will consist of 'marginal valuations' on these capacities. These marginal valuations apply only in short-run investment decisions and are not applicable in the long-run because large amounts of capacity may be available.

3.2.1.4 Empirical Applications of the Model

The primal solution yields the optimal or most efficient pattern of shipments between origins and destinations. This minimum cost solution is efficient in the sense that the prescribed set of demands cannot be satisfied at a lower total cost. Similarly, the system of equilibrium prices obtained from the dual provides a situation in which further shipments from any origin to any destination not included in the equilibrium situation cannot be made at a profit.

The relevant aspects of the results or output from a solution to the transportation model can be be summarized as follows:

1. Total Cost ($\sum \sum Xij\ Tij$).
2. Shipment Pattern or the Xij's that appear in the optimal solution. These are the minimum cost flows of the commodity among regions.
3. The Marginal Values ui and vj. These are the shadow prices at the origin and the destinations, respectively. The difference between them (vj - ui) is the optimal regional price differential in terms of freight rates. If the ui's and vj's are uniquely determined, then the ui's indicate the saving or cost of shifting one unit of production among the u's while the vj's indicate the saving or cost of shifting one unit of demand among the v's.
4. Equilibrium Prices. These are the prices of the commodity consumption for surpluses or deficits for all regions. In order to find equilibrium prices, $ui + Tij < Vj$, if i ships to j, and $vj - Tij < ui$, if destination j receives from i. These can be calculated if the actual prices at both the origins and destinations are available.

Many economic problems can be placed within the general format of the transportation problem of linear programming. This technique can be utilized for the analysis of a plant or firm, an industry, a national economy, and even the world economy. The original formulation of the transportation problem by Hitchcock can be extended to consider other types of costs apart from freight rates. This consideration enables the objective function to include production cost, processing cost, storage cost, as well as freight rates. If these costs are directly proportional to the quantities produced, processed, and stored the extension of the Classical Transportation Problem is straightforward. In such a formulation, the costs that are associated with each origin or destination can be incorporated in the transportation cost in the model.

In the United States, applications of the transportation model to empirical issues include the studies of Fox (1953) on the pattern of livestock feed economy; Judge & Wallace (1958) on the spatial equilibrium price of beef; Goldman (1958) on the optimal geographic distribution of the steel industry; Henderson (1958) and Silberberg (1964) of the shipment of coal; Kotch & Snodgrass (1959) of the location of tomato processing industry; and Morrill & Garrison (1960) of the inter-regional pattern of trade in wheat and flour. In Britain, Land (1957) applied the model to the shipment of coal and Ghosh (1965) applied the transportation model to the Indian cement industry.

There are also a number of empirical applications of the transportation model in the Soviet Union. Kondor (1966) employed the model in his study of the Hungarian sugar beet industry while Abouchar (1967) applied it to the pre-war Soviet cement industry. Abouchar's results indicated that a more rational allocation in the cement industry could have been achieved if the long-run problem of locating new capacity did not emphasize production costs to the neglect of total delivered costs. Other applications of the model in the Soviet Union include that of Anderson (1967) to fodder and livestock production in the Ukraine; and of Barr (1970) to the location and flow pattern of the Soviet wood-processing industry.

Most of these studies were chiefly concerned with determining equilibrium prices that were consistent with the pattern of freight rates between regions and thus, in obtaining the most efficient pattern of shipments. Barr & Smillie (1972) however, suggested that in problems where the spatial configuration of flow patterns is important, the alternative optimal solutions and good sub-optimal solutions should also be investigated.

3.2.1.5 Extensions of the Classical Transportation Model

The standard transportation problem can be extended in several ways. For example, it may be expanded to include many commodities and different transport modes. It may also be modified to consider the situation in which the routes are subjected to capacity limitations.

The Multicommodity Transportation Problem

Multicommodity Transportation Problem is obtained when the CTP is expanded to take more than one commodity into consideration. If k denotes commodity, where k=1,....,h then the objective function is as follows,

$$\text{MIN } Z = \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{h} Tijk\ Xijk \qquad (8)$$

Where,

Xijk is the amount of flow of commodity k on link ij
Tijk is the unit freight rate of shipping commodity k on link ij
m is the number of sources
n is the number of destinations
h is the number of commodities

Subject to the constraints,

$$\sum_{j=1}^{n} Xijk \leq Sik \qquad \begin{matrix}(i=1,....,m)\\(k=1,....,h)\end{matrix} \qquad (9)$$

This constraint means that the total amount of commodity k that leaves source i must be less than or equal to the supply of commodity k at that source.

$$\sum_{i=1}^{m} Xijk \geq Djk \qquad \begin{matrix}(j=1,....,n)\\(k=1,....,h)\end{matrix} \qquad (10)$$

This constraint means that the total amount of commodity k that arrives at destination j must be less than or equal to the demand for commodity k at that destination.

$$Xijk \geq 0 \qquad \text{for all } i,\ j,\ k \qquad (11)$$

This constraint indicates that no negative shipments are allowed.

The dual is as follows,

$$\text{MAX} \quad Z' = \overset{h}{\underset{k=1}{}} \; \overset{n}{\underset{j=1}{}} \; v_{jk}D_{jk} - \overset{h}{\underset{k=1}{}} \; \overset{m}{\underset{i=1}{}} \; u_{ik}S_{ik} \qquad (12)$$

Ford & Fulkerson (1958); Tomlin (1966) and Creamer et al (1970) discussed multi-commodity transportation problems. O'Sullivan (1971) applied the transportation problem to the movement of eleven categories of commodity by road in Great Britain in 1964. In this study, the two export commodities, cocoa and palm kernels are considered separately.

Capacitated Multi-Commodity Transportation Problem

The multi-commodity transportation problem can be extended to situations in which some routes are subjected to capacity limitations by imposing an upper limit on the amount of flow that is permitted along each link. This may be relevant when routes are limited in total flow of traffic which they can accomodate, due to the type and quality of the road, loading facilities and local authority restrictions. In such a formulation, the total flow of the commodity on each link from each origin i (i=1,.....,m) to each destination j (j=1,.....,n) is bounded by a positive value Cijk which is the capacity of link ij for the transportation of commodity k. The capacity constraint is as follows,

$$\sum_{k=1}^{h} X_{ijk} \leq C_{ijk} \qquad \begin{matrix} (i=1,\ldots\ldots,m) \\ (j=1,\ldots\ldots,n) \end{matrix} \qquad (13)$$

If capacity were taken into consideration, then saturated linkages would constitute bottlenecks to the increased utilization of the transportation network.

Multi-commodity flows over a network can be simplified if there are specific sets of demands and supplies for each commodity. In such problems, it is not appropriate to lump these commodities together even if the unit costs of transporting the commodities are the same. It has been illustrated the two commodities being considered in this study namely, cocoa and palm kernels, can be considered as separate problems when link capacities are not considered.

Multi-Mode Transportation Problem

A multi-mode transportation model is required when more than one mode of transport is available. If r denotes mode, where r=1,.....,s then, the multi-mode character of the single-commodity problem can be incorporated by the addition of a third subscript, so that the objective function is as follows,

$$\text{MIN } Z = \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{r=1}^{s} Tijr\ Xijr \qquad (14)$$

Where,

Xijr is the amount of flow by mode r on link ij
Tijr is the unit freight rate of shipping by mode r on link ij
m is the number of sources
n is the number of destinations
s is the number of modes

The constraints and the dual similarly take on the third subscripts as in equations (9 - 12), and are also summed over each mode.

Williams & Haley (1959) presented a specialized algorithm for the transportation problem involving 'p' transport modes where ($p > 1$). They applied the multi- mode model to the mining industry, whereas Dent (1966) applied it to the transportation of wool in Australia. Berge & Ghouila-Houri (1965) demonstrated that when more than one mode is available for shipping a product from i to j, it is possible to substitute a single mode and thus to obtain a simple solution to the original multi-mode problem. This is achieved by assuming that the modes are a number of different 'routes' joining two points in the same direction so that a single 'route' can be substituted. Haley (1963) demonstrated the use of a computational algorithm based on the simplex method for solving multi-mode transportation problems. Dent (1966) applied the multi-mode transportation model to the spatial distribution of wool in Australia.

The multi-mode transportation problem becomes even more complicated when capacity restrictions are imposed and several commodities are being considered. In such situations, some commodities may be better suited to specific modes and the goal of the optimization procedure is to select both shipments and mode in an optimal way.

Dantzig (1955); Dantzig & Ferguson (1956); Charnes & Cooper (1957); Ford & Fulkerson (1957); Wagner (1958, 1959) discussed algorithms for solving the capacitated or multi-dimensional transportation problems. Haley (1962, 1963) discussed multi-index or solid transportation problems and demonstrated that it is more convenient to think of such problems as a block in which the layers form restricted transportation problems. Glover et al (1974) and Langley et al (1974) presented methods of finding equivalent transportation problem formulations for capacitated networks.

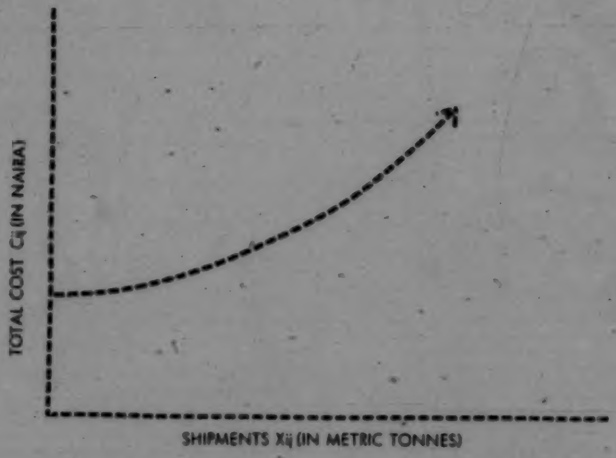
3.3 Methods and Applications of Non-Linear Transportation Problem of Linear Programming

In a linear transportation problem, the objective function is linear because the transportation cost (Tij) is a parameter and does not change regardless of the amount shipped (Xij). This is not realistic because in practice, average cost is expected to vary with the quantity shipped. Non-linearity in a transportation problem results however, when the total transport cost is not linear with respect to shipments.

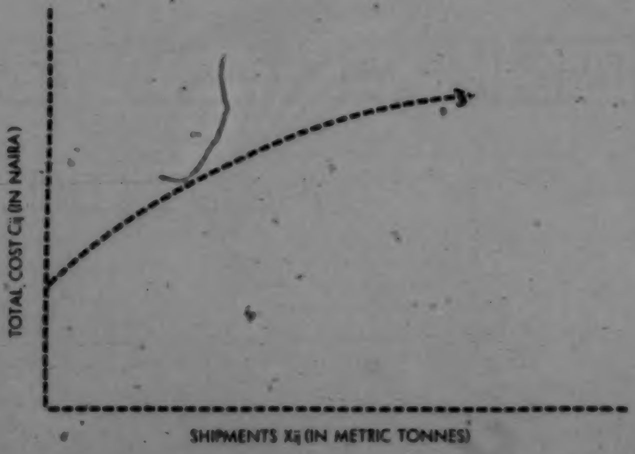
Non-linearity in the objective function may arise in the following way. If transportation capacity is a bottleneck, average cost may increase at an increasing rate beyond the maximum capacity specified for each route. Consequently, the total transport cost will be convex (non-linear) as shown in Figure 15(a).

Hadley (1964) demonstrated that this type of problem can be solved by obtaining a polygonal approximation to the

FIGURE 15. GRAPHICAL REPRESENTATION OF NON- LINEAR CONVEX AND CONCAVE TRANSPORTATION PROBLEMS.



(a) CONVEX TRANSPORTATION PROBLEM



(b) CONCAVE TRANSPORTATION PROBLEM

objective function. Weintraub (1974) presented a primal algorithm for solving network flow problems with convex costs. Although non-linear convex cost functions are conceivable theoretically, they seldom occur in practice, although they may arise in stochastic programming problems.

Concave transportation cost functions, in contrast, are more likely to occur in practice. Concavity in the objective function may be due to an inventory problem. For example, there may be economies in holding large amounts of inventory, in which case the amount of inventory varies approximately as the square root of shipments going through a warehouse, thus introducing concavity. Under these conditions, average cost falls as shipment increases as shown in Figure 15(b). Szwarc (1971) identified this as a paradox which arises when a Transportation Problem admits to a lower post-optimal cost solution by shipping larger quantities of goods over previously determined routes. Concave transportation problems are known to be difficult to solve, for although a local optimum may be found there is no guarantee that this will coincide with the global optimum.

Baumol & Khun (1962); Balinski & Gomory (1964); Gray (1971); Kennington & Unger (1973) and Billheimer & Gray (1973) have discussed the non-linear and fixed cost Transportation Problems and approximative procedures for solving them.

3.4 The Transhipment Problem

3.4.1 The General Formulation of the Transhipment Problem

Orden (1956) expanded the Transportation Problem to include the possibility of transhipment through origins and destinations. This approach is appropriate when the route from i to j via an intermediate point, l, is less costly than a direct route even though the transhipment route entails a longer geographical distance. The intermediate point may possess certain advantages, for example, storage facilities. An important reason for transhipment is that direct links between locations are often not available, in which case the transhipment route is infinitely cheaper than the direct route. This means that a location may both receive and ship various amounts of the commodity and shipments can be made between any pair of locations in any direction. Therefore, the classical Transportation Problem, which usually entails direct transportation from origin to destination is only a special case of the Transhipment Problem.

The Transhipment Problem reduces to the standard Transportation Problem if each point is assumed to be two points, one acting as a shipper and the other as a receiver. Computational considerations require that a large artificial stockpile of the good, Q, be assumed to exist at each transhipment point. This stockpile must be large enough to handle all the flows. In fact, the withdrawals from and compensating additions to the stockpile are equivalent to transhipment. These stockpiles drop out of the final solution, appearing as shipments from points to themselves at zero cost.

In the ultimate case, where every point is a transhipment point, the transhipment problem assumes a structure similar to the transportation problem. The objective function is as follows :

$$\text{MIN } Z = \sum_{i=1}^{M} \sum_{j=1}^{M} T_{ij} X_{ij} \qquad (15)$$

Where M = m + n

Subject to the constraints,

$$\sum_{j=1}^{M} X_{ij} \leq S_i + Q \qquad (i=1,\ldots\ldots,M) \qquad (16)$$

$$\sum_{i=1}^{M} X_{ij} \geq D_j + Q \qquad (j=1,\ldots\ldots,M) \qquad (17)$$

$$X_{ij} \geq 0 \qquad \text{for all } i, j \qquad (18)$$

$$Q \geq \sum_{j=1}^{n} D_j \qquad (19)$$

The dual of the transhipment problem is essentially that of the transportation problem. The Transhipment Problem can also be extended to take more than one mode or commodity into consideration.

Orden's presentation of the transhipment problem did not consider the existence of intermediate transhipment points. In most cases, the transportation network consists of m external sources, n external destination and g intermediate points which may serve as transhipment centers. Garvin (1960) demonstrated that pure transhipment centers which are neither origins nor destinations may be accomodated in the original model by treating them as origins or destinations with no supply or demand capacity of their own.

3.4.2 Empirical Applications of the Transhipment Problem

The transhipment formulation is particularly useful for solving multi-mode transportation problems because its framework is best suited for taking the comparative advantages of the different modes of transportation into consideration. In such formulations, some types of commodity may be better suited to certain modes than others and the goal of the model is to select both shipments and modes in an optimal way. Haley (1967) illustrated this advantage when he expanded the problem to deal with cases in which more than one mode of transportation (road and railway, for example) exists. Transhipment is accomplished by assuming that each node has separate loading/unloading bays for road and railway transport. Within this framework, transhipment costs for inter-modal transfers can be incorporated into the model.

Berge (1962), Hadely (1962), and Dantzig (1963) have demonstrated the equivalence of the CTP and the Transhipment Problem. Wagner (1959) and Malek-Zavarei & Frisch (1972) demonstrated that this equivalence can be extended to problems with fixed costs. Quandt (1960) presented an extension of the capacitated transportation problem which considered transhipment through several cities. Tyrchneiwiez & Tosterud (1973) applied the transhipment model to grain collecting, handling and distribution in the Boissevian region of Canada. Srinivasan (1974) developed a transhipment formulation of cash management problems, which allows the possibility of transfering cash between sources. Ladd & Lifferth (1975) applied a multi-period transhipment model to shipping grain in the region of Fort Dodge, Iowa. Markland (1975) summarized the development and implementation of the transhipment formulation of linear programming for analysing a multi-commodity network having milling-in-transit features as used by a major American food processor. Haaland (1977) applied a transhipment model to grain shipment in a hypothetical situation of post-nuclear attack.

Hadley (1962) demonstrated that it is not necessary to calculate cost of shipping between each origin and each destination in the Transhipment Problem. The minimum cost schedule that will meet the destination requirements is also the solution to the minimum cost of shipping from i to j. Since the shortest path problem is that of shipping a product from one set of locations to another set of locations in such a way that the total cost involved is a minimum, the solution to the Transhipment Problem is also the Shortest Path between i and j. Thus, the Transhipment

Problem can be reduced to the Transportation Problem using the Shortest Path algorithm. This approach has been applied in this study.

3.5 Solution Algorithms for Solving the Transportation Problem

3.5.1 General Background

Stringer & Haley (1957) and Snider (1959) discussed the use of analogue methods for solving Transportation Problems. Vidale (1956), Hadley (1962) and Dantzig (1963) discussed the application of elementary concepts in graph theory to solving transportation problems. These methods are very limited in scope and can only be applied to small sized problems so they are not discussed further.

Generally, a linear programming problem is designed to find non-negative values for the variables in a given set of linear inequalities or equations expressed in these variables. These values must satisfy the given constraints and also maximize or minimize some linear function of the variables. The equation which expresses this linear function is called the objective function.

Linear programming problems which involve only two variables can be solved graphically. In this approach, the intersection of the linear function which yields the optimal value of the objective function or an extreme point, is easily identified. The geometric interpretation of such problems contributes considerably to the intuitive understanding of solutions to linear programming problems.

It is not possible to solve problems with higher dimensions geometrically, therefore the algebraic approach is used for solving such problems. In the algebraic method of solving linear programming problems, any solution which satisfies all the constraints is called a feasible solution, and any feasible solution which maximizes or minimizes the objective function is called an optimal feasible solution.

The linear programming problem can be expressed in matrix notation. The standard matrix form for a linear programming problem AX=B has the following objective function,

Minimize CX,

Subject to the constraints,

$AX \geq B$

$X \geq 0$

Where,

A = An m x n matrix of coefficients
C = Cost vector
B = Total availabilities or demand constraints
X = Optimal allocations or shipments

The first set of contstraints of a linear programming problem consists of m simultaneous equations in m x n unknowns. The second constraint is the non-negativity constraint of linear programming which demands a non-negative solution to the set of equations.

The dual is as follows,

Maximize $R^T Z$

Subject to the constraints,

$A^T Z \leq C^T$

$Z \geq 0$

Generally, Max $R^T Z$ = Min CX

Although an infinite number of solutions may exist in a consistent system of linear equations, there are a finite number of basic solutions. These basic solutions are equivalent to extreme points in the graphical solution. A basic solution is obtained by setting n-m variables equal to zero and solving for the other variables. The variables that are not set equal to zero are known as the basic variables. All the basic solutions can be obtained and the solution which yields the optimal value of the objective function can be selected. However, this procedure is extremely inefficient because the number of basic solutions or extreme points increases very rapidly as the number of variables increases. Moreover, an examination of the basic solution will not determine whether the problem has an unbounded solution.

It has been demonstrated that if a feasible solution to a linear programming problem exists, then there also exists a feasible solution with at most m variables different from zero, which is a basic solution. This means that an optimal solution to a linear programming problem need not have more than m variables different from zero (where m is the number of constraint equations). This unique property of basic solution in linear programming problems has enabled some rational optimizing procedures for solving these problems to be developed. It has also proved very useful in developing iterative procedures for solving linear programming problems. These iterative techniques lie between the extremes of examining all basic solutions and of obtaining an explicit expression for the optimal solution directly. In fact, there is no algorithm for obtaining an optimal solution to a linear programming problem in which the numerical values of the variables are computed directly.

The most commonly used techniques for solving linear programming problems are as follows:

1. The Primal Simplex Method in which the initial feasible solution is based on the primal problem and therefore yields an optimal solution to the primal problem.
2. The Dual Method in which the dual solution of the original problem is treated as the starting solution.
3. The Primal-Dual Method which solves restricted primal and dual problems in order to obtain the optimal solution to the entire problem.
4. The Network Solution Approach.

All these techniques need a starting solution which can be obtained in various ways depending on the nature of the problem.

3.5.2 The Transportation Problem

3.5.2.1 The Starting Solution in the Transportation Problem

The starting solution in a transportation problem is a basic feasible solution in which m+n-1 variables or Xij's are positive. A well chosen initial feasible solution can considerably reduce the total number of iterations required to reach an optimal solution. Since there is no obvious starting solution for the problem, the following methods are used for obtaining an appropriate starting solution.

1. Ship Most At Least Cost (SMALC) Rule. This simple approximation method for solving the transportation problem is based on the fact that the transportation problem always has a feasible solution and therefore an optimal feasible solution. The method consists of finding which route involves the lowest cost and shipping as much as possible along this route. Then, shipping as much as possible along the second-lowest cost route, and so on, until all supplies have been satisfied. Since this method is based on an intuitive notion, it may not always yield an optimal solution. It is also tedious to apply to large networks.
2. The 'north west' corner rule discussed by Larnes (1961), Dantzig (1963) and Hillier & Lieberman (1967). It starts from the first cell or the northwest corner and satisfies either an origin or a destination requirement. It then moves to the next cell and satisfies either a

second origin or a second destination requirement. It continues in this way, satisfying at each step either an origin or a destination requirement until m+n-1 positive Xij's are obtained. However, the basic feasible solution obtained from the northwest corner rule may be far from optimal since costs are not taken into consideration.

3. This consists of other methods for obtaining an initial feasible solution which take costs into consideration. These methods assign a positive value to one variable and at the same time satisfy either a row or a column constraint or a combination of both, at each step. Thus, these techniques cannot yield more than m+n-1 positive variables because after m+n-1 steps, m+n-1 constraints are satisfied and the remaining constraint is automatically satisfied. Since they take costs into consideration, they yield basic feasible solutions which are closer to the optimal solution. They include Vogel's Approximation Method presented by Rienfeld & Vogel (1958) and Charnes (1961); Minimum Entry Method discussed by Kuhn & Baumol (1962); The Column Minimum Rule presented by Hadley (1962); Matrix Minimum Rule presented by Dantzig (1963); and Matrix Minimum Rule by Ranking discussed by Lee (1968). More recent methods of obtaining initial feasible solution that take costs into consideration include the Row Minimum Rule discussed by Hadley (1962), and proved by Srinivasan & Thompson (1973) to perform better than most other rules; Two

Smallest in a Row Rule and Row-Column Minimum Rule discussed by Srinivasan & Thompson (1973); Modified Row Minimum Rule presented by Srinivasan & Thompson (1973) and by Glover, Karney, Klingman & Napier (1974).

After the initial basic feasible solution has been determined, the appropriate systematic procedure is used for adjusting this solution until the optimal solution is obtained. The method employed in moving systematically from one extreme point to another in order to obtain the optimal solution depends to a large extent on the method of obtaining the starting solution. Some problems may be better suited to a particular starting solution than another. For example, Gavish, Schweitzer & Schlifer (1977) discussed three recent improvements and modifications to the Modified Minimum Rule. They compared the use of the Chain Rule, Minimal Weight Tree Rule and the Criss Cross Rule for obtaining basic feasible solutions which would minimize the number of zero pivots and found that the Chain Rule performed better than all the others. The computer program LPTRNS, employed in this study obtains the initial basic feasible solution by employing the 'north-west' corner rule.

3.5.2.2 The Primal Simplex Method

The Simplex Method, developed by Dantzig (1958), is one of the most commonly used iterative techniques for solving linear programming problems. He illustrated that since the Transportation Problem can be cast into the standard linear programming form (i.e. AX = B), the Simplex Method can be used for solving such problems. Although the Simplex Method is a technique for obtaining the optimal values for variables related in a system of linear inequalities, it is more convenient to work with equations than with inequalities. Therefore, additional variables called slack variables, are usually introduced in order to convert the inequalities into equations and to obtain a system of simultaneous linear equations.

The Simplex Method proceeds in systematic steps from an initial basic feasible solution, through other basic feasible solutions, to an optimal basic feasible solution. In this method, provided degeneracy never occurs, it is possible to reach an optimal solution in a finite number of steps by changing a single vector in the basic solution, one at a time. The vector with the largest positive differential value is introduced in the basic solution while another vector is removed. These steps are taken in such a way that the value of the objective function at each step or iteration is better than that at the preceeding step. In fact, the method is equivalent to moving systematically from one basic feasible solution or an extreme point to another until an optimal extreme point is reached. The optimal solution is obtained when no further improvement is possible.

Most of the computer programs that are available for solving the Transportation Problem are based on the primal problem. Klingman, Napier & Stutz (1974) published a Transportation Problem generator (NETGEN) which operates within the primal framework. Glover, Karney & Klingman (1973) developed the primal Simplex Code PNET while Glover, Klingman & Stutz (1974) developed a faster Simplex code PNET-1 for capacitated Transportation Problems.

3.5.2.3 The Dual Simplex Method

In the dual Simplex Method, the basic feasible dual solution to the original problem is treated as the starting solution. Then, as in the primal Simplex Method, the dual method proceeds in systematic steps from this initial basic feasible solution or an extreme point to other extreme points until the optimal solution is obtained. In the dual Simplex Method, the criteria for inserting and removing a vector are those for the dual rather than the primal problem. The procedure employed in moving from one step to the next step gives an optimal solution at a point where the corresponding primal solution is both feasible and optimal.

This method is very useful in problems where additional artificial vectors are needed in order to apply the Primal Simplex Method. Lemke (1954) ; Glover (1972) and Glover and Napier (1972) illustrated the dual method of solving linear transportation problem. Glover, Karney & Klingman (1972) developed a code (HOT-DAM) which determines a dual feasible starting solution for a capacitated Transportation Problem.

3.5.2.4 The Primal-Dual Method

The Primal-Dual Method solves restricted primal and dual problems in order to obtain the optimal solution to the entire problem. It begins with a solution to the dual problem and obtains vectors that should be included in the primal basis in the next step from this problem. When all the vectors satisfy the optimality criterion in the primal basis, a new dual solution is formed and the same process continues until an optimal solution is obtained. Each time a new solution to the dual is found, there is a decrease in the dual objective function so that when a feasible solution to the primal is found, it is also optimal.

Dantzig, Ford & Fulkerson (1962) applied the primal-dual method to a capacitated transportation problem. Ford & Fulkerson (1962) developed an algorithm for network flows which employs a primal-dual feasible starting solution. Balinski & Gomory (1964) solved the Transportation Problem by employing the primal-dual method.

3.5.2.5 The Network Method of Solving the Transportation Problem

The network solution to the Transportation Problem can be described as the problem of finding maximal flows in connected networks containing several sources and sinks. It starts off at one source and branches along links of positive capacity from that source towards a sink. The link capacities are then adjusted and the same operation repeated for the new network. The same procedure is repeated for all the sources in order to obtain the optimal solution. Thus, it is a general method for solving problems sequentially or dynamic programming. The procedures employed by the method ensures that, regardless of the shipments which have been made in the preceeding stages, that combination of shipments which yield the optimal pattern for the system is chosen.

Bellman (1958) originally illustrated the application of this princple of optimality to the Transportation Problem. Further adaptations and modifications of this earlier work include the presentations by Berge (1962); Ford & Fulkerson (1963); Williams (1964); Wets (1966); Beale (1968); Milder (1969); and Chandrasekaram & Rao (1977).

3.5.2.6 Relative Efficiency of the Various Formulations

Over the past few years, there has been much controversy as to which of these approaches namely, Primal, Dual or Primal-Dual Simplex Method, is more efficient for solving the Transportation Problem of linear programming. While Srinivasan & Thompson (1973); Barr, Glover & Klingman (1974); Glover, Klingman & Stutz (1974); and Jacobsen (1978) were demonstrating the superiority of the primal Simplex Method, Hatch (1975) argued that the Primal-Dual method is superior because it is less sensitive to problem size and density problems than the primal Simplex Method. The most efficient computer programs available use the primal although this may be due to a bias in the research effort in favour of the primal.

It has been illustrated that the choice of algorithm is of minor importance as long as efficient computer program is employed. The computer implementation in terms of code design and programming technique far outweighs the relative efficiency of the algorithm or basic methodology employed in formulating the problem.

3.5.3 Various Methods of Improving on the Efficiency of the Solution Techniques

3.5.3.1 Modified Simplex Method

In the Simplex Method, whenever any vector is removed and another vector introduced in the basic solution, a large number of operations (multiplications and divisions) are performed to reflect these changes before going on to the next iteration. These operations take a lot of computer time and may give rise to considerable rounding-off errors. In large problems, after many iterations, the rounding-off errors caused by performing the operations many times, can become quite significant. This limits the size of the problems that can be solved by the Simplex Method.

The Modified Simplex Method, discussed by Hadley (1962) among others, allows rounding-off errors to be reduced by performing the operations on the inverse of the basis instead of transforming the basis at each iteration. If the number of iterations to be performed is large however, it is quite time consuming to invert the basis matrix. In fact, some special judgement is demanded from the researcher in order to determine whether it is advisable to invert the basis or not.

3.5.3.2 Special Characteristics of the Transportation Employed to Improve Efficiency

Due to the special structure of the coeffifient matrix (A) in the Transportation Problem, more efficient techniques than the Simplex Method namely, the Stepping Stone Technique and the U-V Algorithm, have been developed for solving the transportation problem. This is in fact advisable because the Simplex Method cannot handle practical transportation problems which are usually very large in size. Even if such large problems can be dealt with, computer time will be much larger than is necessary.

The following unique characteristics of the Transportation Problem have enabled efficient techniques that require fewer computations than the Simplex Method to be developed for solving this class of linear programming problems.

1. The coefficient matrix of the transportation problem has m+n rows and m x n columns. This is illustrated by the general form of the Transportation Tableau.
2. The rank of the coefficient matrix (A) is m+n-1, therefore if one constraint is dropped, the remaining m+n-1 constraints are independent. This means that in a transportation problem with m origins and n

destinations, there are m+n-1 positive shipments in a basic feasible solution, if the solution is not degenerate.

3. The coefficients of the matrix (A) in the Transportation Problem are all 1 or 0 and the problem of finding the terms or the values of the variables associated with these coefficients is much simpler. Dantzig (1963) considered this property of the Transportation Problem as the problem of finding a permutation of ones in a matrix of zero's and one's.

In addition, the Transportation Problem and other related assignment and allocation problems have the integrality property which demands that every coefficient of the matrix (A) is an integer. Thus if supplies and demands are integers, all basic feasible solutions, and consequently the optimal basic solution, have all positive shipments as integers. This property results from the physical nature of such problems. Intuitively, this means that if it is profitable to ship a fraction of any unit to any destination, then it is profitable to ship as large a quantity as possible. Since an integral number of units are required at each destination, an integral number of units will be shipped.

3.5.3.3 The Stepping-Stone Algorithm

In order to determine whether a given basic feasible solution to a transportation problem is optimal, the opportunity cost for the cells that are not in the basis are calculated. Due to the large number of possible solutions to be examined before an optimal solution is found, a systematic procedure is used for stepping from one solution to another. The stepping-stone method is the procedure normally used and it has been discussed by Charnes & Cooper (1954); Glover (1970); Glover & Klingman (1970); Glover & Karney (1972); Glover, Klingman & Karney (1972) among others.

The method is as follows. Starting from cell(i,j), move around the loop involving (i,j) with the basis cells and alternatively assign plus and minus signs to the costs. If one or more opportunity cost is greater than zero, then the value of the objective function can be reduced further. In a minimization problem, the optimal solution is obtained when all opportunity costs are less than or equal to zero.

Due to the integrality property of the Transportation Problem, the stepping-stone algorithm requires only simple arithmetic operations of additions and subtractions. This reduces the time for making complex calculations and also reduces storage problems when a digital computer is employed. This method makes it possible for the problem of rounding-off errors, which limit the size of the Transportation Problems that can be solved by the Simplex Method, to be avoided.

Unfortunately, the stepping-stone technique is very tedious to apply, especially to large networks. There are also considerable chances of making a numerical mistake when the technique is being employed.

3.5.3.4 The U-V Algorithm

Dantzig (1951) presented a simpler method than the stepping-stone technique for evaluating the opportunity cost of the cells that are not in the basic feasible solution of the Transportation Problem. This method employs the prices or the dual variables ui ($i = 1, \ldots m$) and vj ($j = 1, \ldots n$) associated with each row and each column of the Transportation Problem Tableau for obtaining the opportunity costs of cells that are not in the basic solution. Thus, in a Transportation Problem with m origins and n destinations, for any cell (i, j), the following conditions must be satisfied.

1. $Zij - Cij \geq ui + vj - Cij$
2. Also, if $Xij \geq 0$, then $ui + vj \leq Cij$.

In a minimization problem, if the value of one or more opportunity cost is higher than the corresponding actual cost then there is a better solution involving less cost. In such a case the cell with the greatest differential in cost is used as a pivot for improving the existing solution. On the other hand, if actual costs are lower than the corresponding opportunity costs, then the existing solution is optimal and no further improvements can be made. Therefore, in the cells that have no shipments in the optimal solution, profits are less than actual costs or negative. For all shipments which are made, profits are exactly zero. This means that producers will ship only to destinations where they can earn at least their differential cost, and that consumers purchase just as much as the surcharge appropriate to their zone. These two opposing interests bring about the minimum cost solution.

The U-V Algorithm involves less calculation than the stepping-stone technique, especially for large networks. Almost all computer programs for solving the Transportation Problem use the U-V algorithm for evaluating the opportunity cost rather than the stepping stone technique. The computer program LPTRNS, that was used in this study, employed the U-V Algorithm.

3.6 Solution Techniques for the Transhipment Problem

3.6.1 The Network Method of Solving the Transhipment Problem

In the Transhipment Problem, it is possible for origins to ship to their ultimate destinations through other sources or destinations. Although this approach increases the size of the matrix, the application of the network approach to solving this type of linear programming problems has not only improved drammatically on the efficiency of solving such problems but also improved on the size of problems that can be solved. In the network representation of such problems, the basic arcs in the network form a tree. A tree is a connected network without any loop and it usually includes all the nodes in the network for any feasible solution.

In recent years, several efficient procedures have been developed which can carry out modified steps of the Simplex Method on the network. Significant computational improvements have been made in developing more efficient algorithms for the representation of the basic trees in the computer. Jacobsen (1966) illustrated the use of the Triple Label Procedure which keeps trace of the basic tree in the network solution by the use of three indices, namely, predecessor, sucessor and brother. Glover & Klingman (1970); Glover, Karney & Klingman (1972); Srinivasan & Thompson (1973); and Jacobsen (1978) have suggested various modifications of the Triple Index Labelling Procedure which are more efficient.

Various attempts have also been made to improve on the methods of selecting the variables that should enter the basic solution and finding the stepping-stone tours or cycles. Balinski (1974); Gavish & Scheitzer (1974); Glover, Klingman & Napier (1974); Barr, Glover & Klingman (1977) and Gavish, Schweitzer & Schlifer (1977) have investigated how to improve on the methods of determining the variable to leave the basic solution and obtained some efficient results.

Since real world Transportation Problems are usually quite sparse in density, any solution which takes density into consideration has computational advantages. It reduces the solution time and also eliminates the need for auxilliary storage which is often required for large problems. Several such improvements have been investigated. These include the Matrix Most Negative Rule discussed by Hadely (1962), Dantzig (1963) and Srinivasan & Thompson (1973); Lot Negative Rule, Row Most Negative Rule, Column Most Negative Rule and First Encountered Negative Rule discussed by Denis (1958) and Srinivasan & Thompson (1973); and Most Negative in Group Rule discussed by Glover, Karney, Klingman & Napier (1974). Srinivasan & Thompson found that the Row Most Negative Rule performed better than the others. This was also confirmed by Gavish, Schweitzer & Schlifer (1977).

In spite of these improvements, the network approach to the Transportation Problem still has some disadvantages. It is tedious to apply to large networks. Updating the reduced costs, the flows in the trees and finding the outgoing arc often requires very extensive search. They also demand a lot of storage space.

3.6.2 The Shortest Path Approach to the Transhipment Problem

This study is not concerned with link capacities therefore the Shortest Path approach to the solution of Transhipment/ Transportation Problem which is more complete and efficient, has been employed. It is based on the fundamental consideration that the problem of finding the minimum cost route from a given origin to a given destination can be considered as a Transhipment Problem. This consideration enables the intermediate nodes to be considered as origins or destinations with availabilities or requirements of zero. The solution of this transhipment problem yields the minimum cost of shipping and the path of minimum cost which is also the Shortest Path.

The formulation of the problem enabled the Transhipment Problem to be reduced to a Transportation Problem by means of the Shortest Path Algorithm. This was achieved by calculating the shortest paths between the origins Oi (i=1,....m) and the destinations Dj (j=1,....n) on the transhipment network and employing these shortest paths, as if they are direct links, in the Transportation Problem. This reduced the size of the problem considerably because it did not involve calculating the paths for the entire matrix. Cascade algorithim for calculating Shortest Paths, presented by Farbey, Land & Murchland (1967) was employed in calculating these paths.

The Shortest Paths which were selected in the optimal solution of the Transportation Problem were then re-interpreted link-by-link in order to identify the actual links over which shipments were made in the optimal model. The computer program used in tracing these links is based on the method of tracing the flows along networks discussed by Ford & Fulkerson (1962).

The previous methods outlined were solving the Shortest Path problem and obtaining the optimal shipping pattern at the same time. This approach reduces the amount of calculation involved as well as the storage space required because instead of tracing the paths and allocating shipments at the same time, it only allocates shipments along previously determined Shortest Paths. This formulation is easier and more efficient for large networks. Its major limitation is that it can only be adequately applied when there is no constraint on the capacity of the links. The approach is appropriate however, for investigating the shipping patterns for export commodities in Nigeria, since link capacities are not considered.

4. Chapter Four THE FORMAL MODEL

4.1 Introduction

This chapter discusses the relevant aspects and underlying economic assumptions of the form of Transportation Problem employed in this study. This formulation of the model is considered apppropriate to the minimization of the cost of transporting cocoa and palm kernels within Nigeria. These commodities are transported from the centers where they are purchased to the seaports, by road, water or rail transport. Since more than one mode of transport is involved, transhipment centers as well as transhipment costs are considered. The model is designed for studying short run effects (1976/77) and no provision is made for the expansion of network facilities.

4.2 General Characteristics of the Model

4.2.1 Assumptions of the Linear Programming Model

In order to employ a linear programming framework, a number of simplifying assumptions were made.

1. Origins and destinations were represented by single towns.
2. The Commodity Board is free to ship export commodities to any port and by any mode it desires. This assumption ensures that the Commodity Board planners can optimize.
3. Transport costs per ton are constant with respect to tonnage shipped. This guarantees that the cost

minimization function is linear. Unfortunately, this assumption makes it impossible for the advantages of economies of scale to be taken into consideration.

4. The total demand at j (Dj) and the total supply at i (Si) are given. This means that availabilities and requirements are fixed since total input is equal to total output.

5. The Transportation Problem assumes a perfectly competitive situation in which a central planning authority desires to minimize the costs of meeting a prescribed set of demands. The optimal solution of the minimum cost delivery system and the dual price system provide a complete description of a perfectly competitive equilibrium. This means that the following conditions are assumed to be satisfied:

    a. Products are homogeneous.

    b. There are such a large number of buyers and sellers that no single buyer or seller can influence prices significantly.

    c. There is complete resource mobility.

    d. There is complete knowledge on the part of buyers and sellers.

    e. The price of a given product varies only by the cost of transportation from the exporting regions to the importing regions.

These conditions which are demanded by the model are not always accurate representations of the real world, although as close approximations of the actual conditions they can still provide very useful answers for many problems.

The results obtained from solving the Transportation Problem can be compared with the existing distribution patterns. The conclusions obtained from this type of comparison would point out the divergence of the existing distribution pattern from a highly abstract market situation. If there are indications that the structure of the industry being analysed is not perfectly competitive, the model can be made more realistic by modifying the relevant assumptions of a perfectly competitive situation. In this case, comparisons made between the model solution and the actual situation would be more meaningful for determining if resources have been efficiently located within the industry.

Kotch & Snodgrass (1959) demonstrated the immense difficulties to be expected from modifying the transportation model to reflect deviations from a perfectly competitive situation. Moore (1959) illustrated that applications of the transportation problem to commodity flows involving numerous firms have been less successful than applications involving a single administration. Therefore, the situation of perfect competition is usually assumed, even if it is not realistic.

4.2.2 Additional Assumptions Employed in the Development of the Model

The model developed for this study is an extended form of the transhipment model based on the following additional assumptions.

1. Road and railway loading/unloading bays as well as road and river loading/unloading docks at the transhipment points are connected to the actual origins and to the actual destinations by links in the network. These links have transportation costs equivalent to the actual transhipment costs at the loading/unloading bays. This formulation enables shipments to start from and to end in actual origins and destinations.
2. Origins, destinations and transhipment points are treated as two or more nodes, one for each mode.
3. Pure transhipment points are distinguished by having zero demand or zero supply, otherwise they are treated in the same way as other nodes in the system.
4. The cost of shipping between a node and itself on the same mode is zero. The cost of travel between a node and itself involving a change from one mode to another is infinity if the node is not a transhipment point and is the actual transhipment cost if the node is a transhipment point.

4.3 The Formal Model Employed in the Study

4.3.1 Choosing the Model Employed

The classical Transportation Problem (Equations 1-7) minimizes the shipping bill while ensuring that all the supplies of the commodity at the origins are shipped and that all destination demands are met. The model assumes that every source is connected to every destination and that direct shipments between all origins and destinations are feasible. It can be represented graphically as a network in which every point is connected to every other point by a link of infinite capacity along which shipping costs do not change regardless of the amount shipped. It has been illustrated however, that this standard Transportation Problem may be expanded to include many commodities, different modes and capacity limitations. In this study, the method of modelling the transportation network takes the different modes into consideration while the assumption of no capacity restriction on the links enables the cocoa and palm kernel shipping problems to be considered as separate problems.

Different strategies are employed in reflecting capacity limitations on transportation network facilities which are usually characterized by capital expenditures and recurring operating costs. One approach is to consider capacity limitation in terms of a given level of service. This means that if transportation capacity is a bottleneck, the average shipping cost will increase at a higher rate beyond the maximum capacity specified for each route. The cost of shipping at a specified level of service is given and after this limit more traffic is still allowed on the system but at an increased cost resulting in a piece-wise linear Transportation Problem or a non-linear Transportation Problem with a convex cost function.

This approach would involve relating the cost of producing the transportation services to the usage of the network facilities and also implies that all users of the network, not only cocoa and palm kernel shippers, must be considered. Secondly, the approach would involve complex policy decisions on the part of the carriers concerning the preferences given to shipping various commodities. For example, if the freight rate on certain commodities such as imported manufactured goods is greater than the freight rate for export commodities, a profit maximizing shipper would give greater preference to shipping imported manufactured goods. Under such situation, data on the shippers rate of substitution between shipping imported manufactured goods and shipping export commodities must be obtained in order to employ this approach adequately. Since these considerations are extremely difficult to be incorporated into most practical problems, this approach of taking capacity into consideration was not taken in this study.

Another approach to optimal capacity conditions on the transportation network is to set an upper bound on the amount of traffic that can flow along each link. Once this limit is reached, no further traffic is allowed. This type of capacity restriction is relevant when routes are limited in the amount and/or type of traffic that they can accomodate due to the quality of the road, loading facilities or local authority restrictions. The approach can be quite realistically applied to situations in which the optimal capacity conditions are fixed over one or a set of planning periods each of which has a limited amount of capital expenditure on transportation. It is particularly relevant to developing countries which are characterized by extreme shortages of investment capital and capacity improvements are limited to a set of indivisible entities such as the addition of an entirely new lane of traffic on the links.

The capacitated multicommodity Transportation Problem with its constraint capacity (Equation 13) represents this approach. In such a model, the shipping cost does not depent on the quantity shipped and the published freight rates can be employed. Also, if capacity were taken into consideration in this way, the dual variables would indicate the links on which higher shipping costs are incurred because of capacity restrictions. Since this model enables the saturated linkages that are consitituting bottlenecks to the increased utilization of the transportation network to be identified, it would be very useful for transportation network planning.

Although it would have been interesting to take capacity into consideration in this study, data on the capacity of the links were not available. Even if such data were available, problems will still arise when other commodities, excluding cocoa and palm kernels, that are shipped along the links are taken into consideration. If it is assumed that the shipments of all other commodities are given exogenously, the capacity constraint is stated as follows,

$$\sum_{K=1}^{2} Xijh \leq Cijk - \sum_{k=3}^{h} Rijk \qquad (20)$$

Where,

$Cijk$ = Capacity of link ij for all commodities

$\sum_{k=1}^{2} Xijk$ = Total quantity of cocoa and palm kernels shipped along link ij

$\sum_{k=3}^{h} Rijk$ = Total quantity of all other commodities, excluding cocoa and palm kernels, shipped along link ij

This model would therefore not only demand data on the capacity of the link but also data on the total quantity of all other commodities, excluding cocoa and palm kernels, shipped along each link. Thus, the problem is not simply a question of availability of data but the problem of working on a sub-system within a bigger system which is applicable to any economy, whether developed or not.

Osayimwese (1973) had already noted the problems involved in the specification of inland transport capacities in Nigeria. He mentioned that even the NEDECO Consultants shyed away from the task of obtaining data on transport capacity in the country. In this study, it is assumed that there are no capacity restrictions on the links, although it may be useful for the railways due to the rolling stock. This is quite realistic because the railway and waterway transport networks have excess capacity and yet are presently underutilized so that they can conveniently handle all shipments of cocoa and palm kernels. Also, the two commodities do not account for a high percentage of freight movement on the roads and it can be safely assumed that they will not cause an excessive demand on the optimum capacities of the road network. Therefore, the uncapacitated Transportation Model with the linear shipping cost function was formulated as a Transhipment Model and employed in the study.

4.3.2 The Formulation of the Transhipment Model

In the Transhipment Model developed, it is possible for origins to ship to their ultimate destinations by transhipping through other sources or destinations. This was achieved by expanding the original Transportation Tableau to reflect origins that may serve as destinations, destinations that may serve as origins and both origins and destinations that serve as transhipment points. This means that in effect, all the nodes in the network (N), can be considered as transhipment points. The nodes in the network consists of the origins (m), the destinations (n) and the transhipment points (p) so that $N = m + n + p$. In this formulation, the objective function is to minimize,

$$\mathrm{MIN}\ Z = \sum_{j=1}^{N} \sum_{i=1}^{N} T_{ij} X_{ij} \qquad (21)$$

Where, $M = m + n + p$

Subject to the following constraints,

$$\sum_{j=1}^{N} X_{ij} \leq S_i + Q \quad (i=1,\ldots\ldots,N) \qquad (22)$$

The total amount of the commodity that leaves a source must be less than or equal to what it produces plus what it tranships. In this formulation, Si is zero if there is no actual supply. This means that the node is either purely a destination or purely a transhipment point with zero supply. Q is the stockpile which must be large enough to handle all transhipments. Usually, it need not be greater than the total quantity that is shipped.

$$\sum_{i=1}^{N} X_{ij} \geq D_j + Q \quad (j=1,\ldots\ldots,N) \qquad (23)$$

The total amount of the commodity that arrives at a destination must be greater than or equal to the demand at that destination plus what it tranships. In this formulation, Dj is zero if there is no actual demand. This means that the node is either purely an origin or purely a transhipment point with zero demand.

$$X_{ij} \geq 0 \quad \text{for all } i,\ j \qquad (24)$$

This constraint indicates that no negative shipments are allowed.

The dual assumes a structure similar to that of the original formulation of the Transhipment Problem. It has the following objective function,

$$\text{MAX } Z' = \sum_{j=1}^{N} vj(Dj+Q) - \sum_{i=1}^{N} ui(Si+Q) \qquad (25)$$

Subject to the constraint,

$$vj-ui \leq Tij \qquad \begin{matrix}(i=1,\ldots\ldots,N)\\(j=1,\ldots\ldots,N)\end{matrix} \qquad (26)$$

4.4 Modelling the Transhipment Model Employed in the Study

4.4.1 Modelling the Transportation Network and the Costs (Tij)

In this study, Tij is the unit cost of flow on link ij. The cost data that are employed in the study are the shipping costs, which consists of the usual terminal rates and the actual freight rates, and the transhipment costs. It is recognised that the use of freight rates takes into consideration the capital costs and other costs of providing the transportation services by various modes in only an approximate way. It also ignores the exact costs of producing the shipping services by the transportation firms, and implies that these are useful services provided for the public. The transhipment costs refer to the handling costs at the transhipment points and it depends on the actual method of transfer employed. The method of obtaining costs along the links takes into consideration the fact that each node in the network can be considered as a transhipment point. Figure 16 illustrates the general procedure employed.

4.4.1.1 Setting up the Nodes in the Transportation Network

The model assumes that origins, destinations and transhipment points can to be considered as two or more nodes, one for each mode. If the node is not purely a transhipment point but also produces or demands some quantity of the commodity, then it has another node in addition to these. This additional node can be considered as a warehouse from which goods are loaded or in which goods are off-loaded. If the node is a port, it has another additional node. Figure 16(a) illustrates the general procedure for modelling the transportation nodes on the network and was obtained in the following way.

1. Assume that Node 1 is an origin node that produces some quantity of cocoa or palm kernel (Si). It is served by the road and railway transport modes. Then, in addition to Node 1 which is the actual origin, there are two more nodes namely, Node 1Rail and Node 1Road which represent the respective rail and railway loading/unloading bays at Node 1.
2. Assume that Node 3 is a demand point (a seaport or any of the internal processing mills) which has a specified demand for cocoa or palm kernels (Dj). It is also served by road and railway transport modes. Then, in addition to Node 3 which is the actual demand point, there are

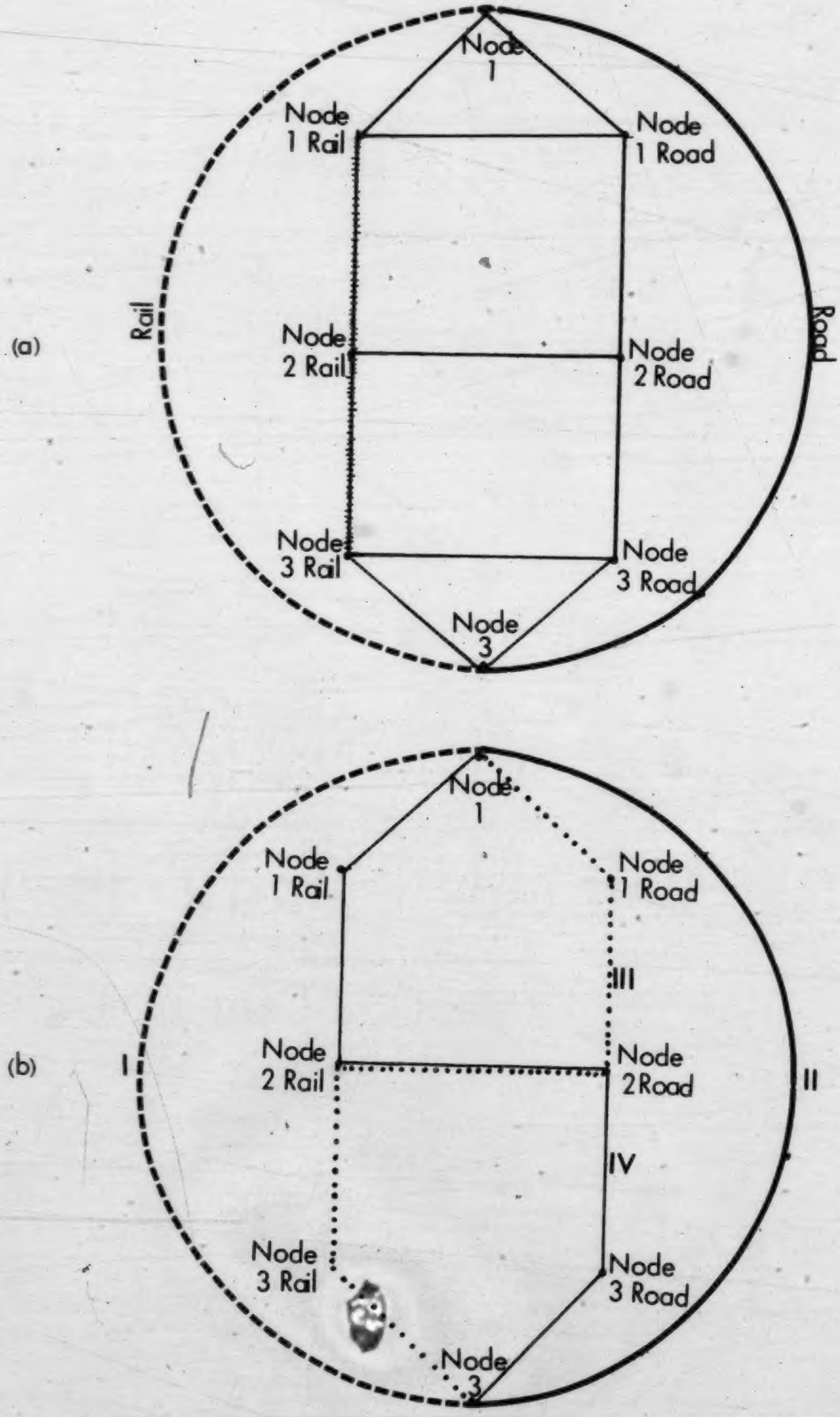

(a)
Node 1
Node 1 Rail
Node 1 Road
Rail
Road
Node 2 Rail
Node 2 Road
Node 3 Rail
Node 3 Road
Node 3
(b)
Node 1
Node 1 Rail
Node 1 Road
III
I
Node 2 Rail
Node 2Road
II
IV
Node 3 Rail
Node 3 Road
Node 3

FIGURE 16. MODELLING TRANSPORTATION NODES, LINKS AND SHORTEST PATHS ON THE NETWORK

two more nodes namely, Node 3Rail and Node 3Road which represent the respective rail and railway loading/unloading bays at Node 3.

3. Assume that Node 2 is purely a transhipment point which does not produce or demand either cocoa or palm kernels(i.e. Si=0 and Dj=0). It is served by road and railway transport modes and is directly connected to Nodes 1 and 3 by road and railway modes. Then, it has two nodes namely, Node 2Rail and Node 2Road.

This formulation enables the cost of transhipment between all modes in each node to be incorporated into the model. It can also be modified to reflect other different conditions on the network.

4.4.1.2 Calculating the Costs Along the Links in the Network

1. Calculating the Costs Along the Links for Different Modes

The direct connections and long-haul freight rates along the directly connected links on the transportation network are considered. If the node i and j are not directly connected, the shipping cost between them (Tij) is infinity. If i and j are directly connected, Tij is the actual unit cost of shipping or the freight rate between i and j. For example, 1Road and 2Road are connected, therefore Tij is the actual freight rate by road between them. Similarly, 1Rail and 2Rail are connected, therefore Tij is the actual freight rate by rail between 1 and 2. The same conditions apply to nodes 2 and 3.

For each transport mode, the freight rate on the directly connected links and the long-haul paths from the origins to the demand points were employed in the model. This means that in addition to freight rates of the direct links such as 1Road-2Road and 2Road-3Road the long-haul freight rate 1Road-3Road was also employed. Also, in addition to the freight rate on the direct links such as 1Rail-2Rail and 2Rail-3Rail the long-haul freight rate 1Rail-3Rail was also employed. These long-haul freight rates are modelled as artificial links (Road and Rail, respectively) in Figure 16(a). The same procedure is employed where railway and waterway transport modes or all three modes are involved.

2. Calculating the Costs Along the Transhipment Links

The transhipment costs are employed in the model to enable inter-modal transfers to be made at the transhipment centers at the expense of the appropriate transhipment costs. The possibility of transhipment enables the modes to provide complimentary services. In order to tranship from one mode to another, the produce is usually offloaded from one mode and re-loaded to the new mode. This transfer is incorporated in the model as a link from a rail to a road node within that center, and the transport cost on this link is the cost of making this transfer or transhipment. Thus, within the transhipment centers, additional links with the appropriate transfer costs link the different modes of transportation to each other. This formulation enables the model to choose the best mode on which shipment should continue through the node on its way to the final destination.

The transhipment costs on the links involving a change from one mode to another is infinity if the node is not a transhipment point and is the actual transhipment cost if the node is a transhipment point. For example, since 2 is a transhipment point, the cost of link 2Road-2Rail is the actual cost of transhipment between the road and railway modes at node 2. Similarly, the costs of links 1Rail-1Road and 3Rail-3Road are the actual transhipment costs between the road and railway at nodes 1 and 3.

3. Calculating the Costs Along the Terminal Links

In order to enable shipments to start from and to end in the actual origins and the destinations, these actual origins and destinations are connected to the respective road and railway loading/unloading bays by additional links. If the transhipment point is a demand point or a port it is also connected to the rail or road node in order to enable shipments made by these modes to arrive at these demand points by any of these modes. In such cases, Tij is equal to the actual cost of loading or offloading at these bays. For example at node 1, the cost of link 1-1Rail is the terminal cost of loading/offloading by rail at node 1 while the cost of link 1-1Road is the terminal cost of loading/offloading by road at node 1. Similar conditions apply at node 3. This formulation makes it possible for different costs for loading or offloading to be incorporated in the model where these costs are different.

All the general procedures outlined are applicable to other expanded formulations. These include the formulations in which there is a waterway mode in addition to road and railway modes, when an origin node is also a processing mill or when a seaport also produces some cocoa or palm kernels.

4.4.2 Obtaining the Shortest Paths

The formulation of the model employed solves the Transhipment Problem by reducing it to a Transportation Problem by means of the shortest path algorithm. The minimization of transportation costs implies that shipments will be made along the shortest paths. Since there is no constraint on the capacity of the links on the network, these shortest paths can easily be calculated and the network over which flows are optimized become simpler. The direct connections between origins (Si) and destinations (Dj) which is assumed in the classical Transportation Problem is then achieved by employing shortest paths obtained from the transhipment formulation of the network as direct links in the Transportation Problem.

Figure 16(b) illustrates the procedure for obtaining the shortest paths on the network. These paths may be long-hauls by any mode between origins (Si) and destinations (Dj). For example, in Figure 16(b), the shortest path I is the long-haul shipment by rail between Node 1 and Node 2 while the shortest path II is the long-haul shipment by road between Node 1 and Node 2. The shortest paths may also involve shipments by two or more modes of transport along the path, as well as shipments through artificial nodes to incorporate transhipments. For example, in Figure 16(b), the shortest path III started-off by road from Node1, transhipped to the rail at Node 2 and arrived at Node 3 by rail. Similarly, shortest path IV started-off by rail from Node1, transhipped to the road at Node 2 and arrived at Node 3 by road. The shortest path algorithm selects the least cost path of shipping from Node 1 to Node 3 from all such shortest paths in the network. In this way, the shortest path algorithm reduces all origin-destination pairs in the network to the type of direct connections between these assumed in the classical Transportation Problem (Equations 1-7).

4.4.3 Tracing the Actual Flows along the Links

The formulation of the Transportation Model employed yields the optimal pattern of shipments from origins (Si's) to destinations (Dj's) along the shortest paths. These optimal flows were then reassigned to the actual links over which shipments were made by tracing these links along the shortest paths selected in the optimal model. For example, in Figure 16(b), if shortest path I (the long-haul shipment by rail between Node 1 and Node 3) was selected in the optimal model, the actual links over this path should be traced along Node 1-Node 1Rail-Node 2Rail-Node 3Rail -Node 3. Similarly, if shortest path III was selected, the actual links should be traced along Node 1-Node 1Road-Node 2Road-Node 2Rail -Node 3Rail-Node 3.

It is possible to accomplish the tracing of these links because there were no constraint on link capacities. If capacity were taken into consideration, assigning flows along these links along the shortest paths might result in overloading some links on the network.

5. Chapter Five MODELLING THE TRANSPORT NETWORK WITH THE DATA OBTAINED

5.1 Introduction

There are immense difficulties to be encountered in obtaining adequate data for modelling transportation problems. These difficulties tend to be much greater in underdeveloped countries where the compilation of reliable data on a nation-wide scale has not yet been accomplished. Despite these data problems, empirical research is necessary in these countries and should be undertaken more often. The data used in this analysis were obtained from field work conducted between May and September, 1978, in Nigeria.

Generally, the Transportation Problem determines the pattern of shipments which minimizes the total cost of transporting known quantities of a commodity at each of m origins to satisfy given demands of this commodity at each of n destinations. Therefore, the data required by the model are as follows,

1. The quantities of cocoa or palm kernel purchased at each origin (S_i).
2. The demands for cocoa or palm kernels at the ports or at the processing industries within the country (D_j).
3. The cost of shipping by each mode and the transhipment costs (T_{ij}).

5.2 The Quantities of the Commodities Purchased

5.2.1 General Background

Almost all the cocoa produced in Nigeria, with the exception that used by the Cocoa Industries Limited at Ikeja, is exported. By 1976/77, the industry was receiving its supply of cocoa from the Marketing Board since it was not allowed to purchase directly from farmers. The quantity of cocoa supplied to the industry in that year was only about 5% of the total purchases of cocoa by the Board.

Although the cocoa sent to Ikeja can be regarded as consumption that took place within the country, it is included in the model because the demand for it within the country may affect the optimal pattern of shipments to other demand points at the ports. This quantity is also considered when the demand at one external destination is investigated because the pattern of shipments to such internal demand points may be influencing the pattern of shipping to the external destination.

The scattered locations in which the processing and marketing of palm oil and palm kernels take place within the country, makes it difficult to have an accurate statistical estimate of the quantities of these commodities consumed within the country. The difference between production and consumption however, determines the quantity to be exported. One can safely assume that the quantities of cocoa and palm kernels purchased by the Boards represent the exportable surplus of these commodities. For example, the negligible quantities of palm oil exported since 1970, and subsequent non-export of this commodity, is largely due to increased demand for the product within the country. As the domestic demand for palm oil increased, emphasis shifted to the palm kernels for export. All the palm kernels purchased by the Marketing Boards, with the exception of the quantities sent to the crushing mills, are for export. Eventually the palm kernel oil, cake and pallets from the crushing mills are also exported.

In recent years, the number of crushing mills in the country has been increased in order to reduce the bulk of the palm kernels for export and also with the aim of promoting local industries. In spite of ambitious plans to keep these crushing mills working at full capacity, evidence shows that due to many mechanical, financial and administrative problems, most of the mills remain non-operational for several months in the year. The most common mechanical problem of the mills is that of producing palm kernel oil with a high percentage of fatty acid content (up to 15% in some cases), which is unacceptable in the world market. When this happens, the crushing mill concerned is closed down while the cause of the mechanical problem is investigated. This is often done in such a hurried and confused manner that record keeping suffers greatly. Because of this and other related reasons, no accurate statistics of the quantities of the palm kernels sent to the crushing mills in 1976/77 were available. However, the data for

November 1977 to June 1978 were obtained and introduced in the 1976/77 model in order to demonstrate what effects the internal demand for palm kernels could have on the optimal pattern of shipments to the ports. These internal demands are also included when the demand at one external destination is considered because they must have to be satisfied as well.

5.2.2 The Commodities Purchased (Si)

The method of keeping records of the quantities of the commodities purchased for export is not uniform. In some cases the records are kept at the very fine level of grading stations. In others they are aggregated according to the Produce Inspection Divisions and in a few cases they are kept at the Provincial level.

Obviously, the optimal solution will depend to a considerable extent on the level of aggregation used because as the model gets more detailed, the solution gets more constrained. It was considered that to base the model on the State level or the provinces would be too aggregated to form a basis for any meaningful recommendation. If the grading stations were used as the unit of analysis, the number of nodes in the system would be too great and the analysis would deal with very small quantities of the commodities purchased at these stations. Therefore, the quantities of the commodities purchased were aggregated according to major Administrative Divisions as delineated in Fig 17. All

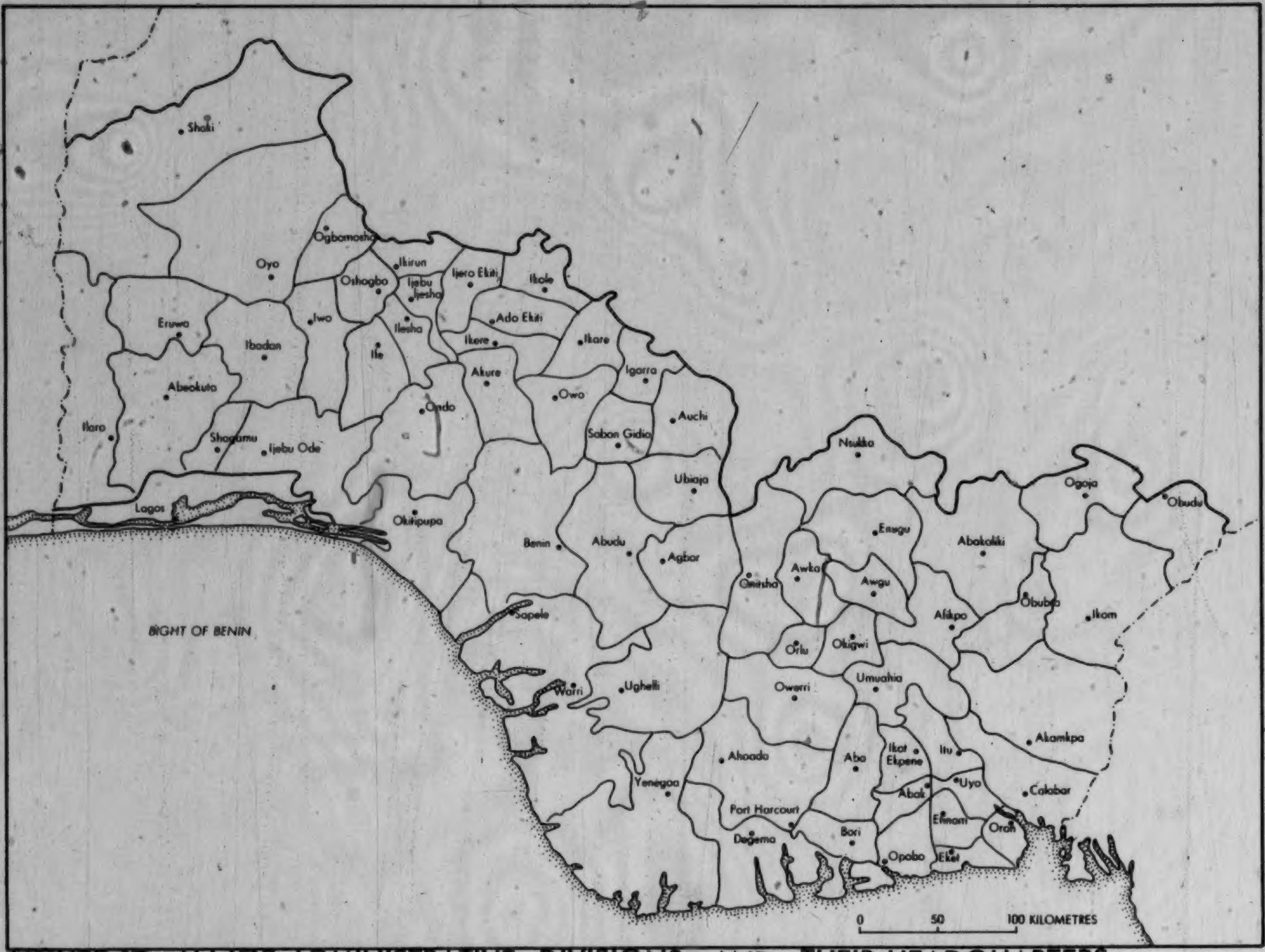

Shaki
Ogbomosho
Oyo
Ikirun
Oshogbo
Ijebu Ijesha
Ijero Ekiti
Ikole
Ado Ekiti
Iwo
Eruwa
Ibadan
Ilesha
Ikere
Ikare
Ife
Akure
Igarra
Abeokuta
Ondo
Owo
Auchi
Ilaro
Shagamu
Ijebu Ode
Sabon Gidio
Nsukka
Ubiaja
Ogoja
Obudu
Lagos
Okitipupa
Enugu
Abakaliki
Benin
Abudu
Agbor
Onitsha
Awka
Awgu
Obubra
Afikpo
Ikom
Sapele
BIGHT OF BENIN
Orlu
Okigwi
Umuahia
Warri
Ughelli
Owerri
Akamkpa
Ahoada
Abo
Ikot Ekpene
Itu
Yenegoa
Abak
Uyo
Calabar
Port Harcourt
Eket
Oron
Degema
Bori
Opobo
Eket
0
50
100 KILOMETRES

FIGURE 17 MAJOR ADMINISTRATIVE DIVISIONS AND THEIR HEADQUARTERS

purchases in each Division were assumed to have originated at the Divisional Headquarters. These are regarded as the supplies or availabilities at the origins (Si).

This assumption does not take the travel costs from the grading stations to the Divisional Headquarters into consideration. Although it facilitates the representation of origins and destinations in the model, it is also liable to other aggregation errors. Despite these difficulties, it is a convenient method of obtaining a uniform and consistent type of aggregation within the area of study.

Shaki, the headquarters of Northern Oyo Division was excluded because no cocoa or palm kernels were purchased in that Division and due to its peripheral location it is almost isolated from other divisional headquarters. On the other hand, although there were no cocoa or palm kernels purchased in Abakaliki Division, Abakaliki was included in the study because it is linked to other Divisional headquarters by road and may therefore serve as a transhipment point. In all, 63 nodes or Divisional headquarters were employed.

The major cocoa growing areas of the Western States depended entirely on earnings from cocoa all through the colonial period. Due to the importance of cocoa in the economy of these States over the years, the Western State Marketing Board is well established and organized in its method of keeping records. It has a statistics section which publishes annual information on export commodities handled by the Board in the Western States. Therefore, this was the source of data on the quantities of cocoa and palm kernels purchased by the three Western States of Ogun, Oyo and Ondo in 1976/77.

The State Marketing Boards in the remaining states do not have a well organized statistics section and so could not supply reliable statistics on the quantities of these commodities purchased. Data on these were obtained from the Produce Inspection Division of the Ministry of Agriculture and Natural Resources in these states. This Division is responsible for the inspection and grading of the produce for export at the grading stations. Table 5 shows the quantities of cocoa and palm kernels purchased at each origin during the 1976/77 produce season. The Commodity Boards could not provide any reliable data on the actual quantities of these commodities shipped from the grading stations to the ports therefore there were no actual shipments against which the optimal pattern of shipments from the models could be compared.

5.3 The Demand for the Commodities (Dj)

5.3.1 The Quantities of the Commodities Exported or Shipped to Internal Demand Points

The model is mainly concerned with the demand for cocoa and/or palm kernels at the various demand points. Some of the centres which produce cocoa and/or palm kernels also demand these commodities. For example, Calabar,

TABLE 5. QUANTITIES OF THE COMMODITIES PURCHASED FOR EXPORT IN 1976/77 (In Metric Tonnes).

	NAME OF SUPPLY POINT	QUANTITY OF PALM KERNEL	QUANTITY OF COCOA
1	IBADAN	41421	53281
2	IFE	14596	13513
3	ABEOKUTA	13445	25765
4	IJEBU ODE	9325	26297
5	IWO	11436	8138
6	ONDO	4382	15535
7	IKIRUN	4374	8892
8	SHAGAMU	418	7970
9	OKITIPUPA	4618	6971
10	OSHOGBO	6837	5520
11	ILESHA	2976	7890
12	ILARO	5747	3967
13	IKARE	2211	4905
14	IKOLE	2456	6484
15	IJERO EKITI	1335	4271
16	OYO	5099	4603
17	IJEBU IJESHA	1745	3227
18	OGBOMOSHO	931	705

19	IKERRE	872	1928
20	AKURE	873	205
21	ADO EKITI	608	2079
22	OWO	1280	1141
23	ERUWA	1209	42
24	ABUDU	449	115
25	AGBOR	3051	5
26	SABONGIDA ORA	1058	3958
27	AUCHI	1923	1672
28	BENIN	1874	1309
29	IGARRA	1405	1373
30	SAPELE	5709	16
31	UROMI	4104	1204
32	UGHELLI	3680	*
33	WARRI	4038	2
34	AWKA	4287	6
35	NSUKKA	11358	*
36	ONITSHA	5003	*
37	ENUGU	5348	*
38	AWGU	586	16
39	ABA	20956	494
40	UMUAHIA	16589	4116
41	OKIGWI	12713	*
42	ORLU	18272	*
43	OWERRI	4127	*
44	AFIKPO	745	*
45	ABAK	11566	*

46	AKAMKPA	892	*
47	CALABAR	3096	88
48	EKET	786	*
49	ETINAM	4010	*
50	IKOT EKPENE	10115	2
51	ITU	2134	25
52	IKOM	177	6695
53	OBUBRA	2443	*
54	OBUDU	911	*
55	OGOJA	1187	245
56	OPOBO	6604	*
57	ORON	4420	*
58	UYO	10015	*
59	PORT HARCOURT	4955	32
60	AHOADA	2318	25
61	DEGEMA	1111	*
62	YENEGOA	1226	*
63	BORI	582	*

* INDICATES NEGLIGIBLE

Port Harcourt, Warri and Sapele produce palm kernels but they are also major seaports and various quantities of cocoa and palm kernels are shipped through them annually. In the modelling of the transport network, these ports are considered as separate nodes that are connected to the actual origins and to other transport modes by the appropriate transport costs.

Lagos does not produce appreciable quantities of cocoa or palm kernels but a high proportion of these commodities from other parts of the country are shipped through Lagos port. It is the capital of Nigeria and the largest port in the country. Ikeja does not also produce either of these commodities but has a cocoa industry (C.I.A) and a palm kernel crushing mill (VON), which demand various quantities of these commodities.

The palm kernel crushing mills constitute internal demand centers for this commodity. Two of these crushing mills, PALMIL and AVOC are located at Abak and Warri, respectively. They are divisional headquarters while Warri is also a port. The other two crushing mills, NIPROC and PALMKE are located at Arondizuogu and Umunze. The demands at these mills were assumed to be made at their respective Divisional Headquarters at Orlu and Awka. There were no data on the palm kernel crushing mill RIVOC at Port Harcourt which was opened later in the study period.

The quantity of each commodity that is exported through any given port is taken as the demand for that commodity at the port (Dj). The quantity delivered at each internal demand point is regarded as the demand for that commodity at that center (Dj). These internal demand points were also considered when the shipments to one external destination were investigated.

Table 6 shows the quantities of cocoa and palm kernels demanded at each port and at the processing industries in 1976/77. Data on the quantities of palm kernels sent to the crushing mills were obtained from the Palm Produce Board Headquarters at Calabar whereas data on the quantities of the commodities exported through the major ports were obtained from the Marketing Board Headquarters in Lagos. The quantity of cocoa sent to the industry at Ikeja was obtained from the headquarters of the Cocoa Marketing Board at Ibadan.

The notion of demand at the ports does not include the notion of variable utilization rates at the ports. In fact, these ports are competing for traffic with each other and while some ports may be underutilized, others may be overutilized. Thus, the throughput of any commodity at a port in any given year is not necessarily a measure of the handling capacity available at the port.

5.3.2 Modification of Si in Order to be Exactly Equal to Dj

It was observed that all purchases of cocoa and palm kernels are not always exported within the same year in which the purchases were made. The exports of these

TABLE 6. QUANTITIES OF THE COMMODITIES EXPORTED OR SHIPPED TO INTERNAL DEMAND POINTS (In Metric Tonnes)

A. INTERNAL DEMANDS

NAME OF DEMAND POINT	PALM KERNELS	COCOA
IKEJA (AVOC)	13681	11528
ABAK (PALMIL)	16641	*
WARRI (EVOC)	13681	*
ORLU (NIPROC)	13671	*
AWKA (PALMKE)	5640	*

B. EXTERNAL DEMANDS

NAME OF PORT	PALM KERNELS	COCOA
LAGOS	107295	173753
PORT HARCOURT	107775	8580
CALABAR	32559	4444
SAPELE	17698	34521
WARRI	5572	*

* INDICATES NEGLIGIBLE

commodities depends largely on the world demand for these crops which fluctuates from time to time. Also, in some years when there are bumper crops, the arrangements to sell the commodities to the world markets lags behind the deliveries of the commodities at the ports. Fortunately, both cocoa and palm kernels are not easily perishable and so can last for 2 or 3 years without deteriorating much in quality.

These surpluses mean that the purchases are not exactly equal to the demand, as required in the model. The model is investigating the optimal patterns of shipping to the ports, therefore it is more realistic to assume that the surpluses originated from the supply points in the previous year. Since the exact locations from which these surpluses originated were not known, the purchases at all the origins were increased in the same proportion as the volume of purchases made in these origins in 1976/77. In this way, the volume of total purchases were made to be exactly equal to the total demands as required in the model. The major difficulty with this approach is that it assumes that the quantities produced at the origins are stable over the years which is not necessarily true but it is the most logical pragmatic approach.

5.4 The Cost of Transportation (Tij)

5.4.1 General Background of Road Freight Transport in Nigeria

The ownership, management and organisation of the road transport business in Nigeria is largely in private hands, while the government is responsible for the provision of infrastructures, enactment and enforcement of road safety regulations, and the issuing of vehicle and driving licences. Passenger fares and freight rates on roads have been rising in recent years for several reasons. These include:

1. Rising cost of vehicles and spare parts.
2. Congestion of the roads and ports which increase the turn around time of vehicles and consequently, operational costs.
3. High rate of accidents resulting in high insurance premiums and high recovery rate for investments on vehicles.
4. Touts or middlemen who contribute nothing to the efficiency of road transport and yet receive a significant share of the fares.

Despite these trends, numerous carrier organizations provide regular freight services from Lagos and other seaports to all parts of the country.

Ideally, rates based on a fixed tonne/kilometer price for road freight traffic could be set up nationally and carriers forced to keep within these rates. The government-owned National Freight Transport Company was formed in 1977 to help in stabilizing road traffic freight rates in the country. However, the pattern of charges is not very rigid and varies widely all over the country. Where the available loading space and the demand for transport services are not in equilibrium, practice shows that market forces take effect, with supply and demand determining the transport price. It was also observed that consignors of regular, large-scale freight shipments usually make annual contracts with carriers.

The road network in the area of study was modelled as a graph and the links were numbered sequentially shown in Figure 18. The freight rate along each link in addition to the long-haul freight rates from the origins to all the major ports were employed in the model. Two types of data on road transport costs consisting of the transport differential rate of the Commodity Boards and the transport cost by road as set by transport firms were employed.

5.4.2 Transport Differential Rates of the Commodity Boards

These were obtained from a circular which the Boards sent to the licensed buying agents for both cocoa and palm kernels for the 1976/77 produce season. According to the circular, the rate was 7 kobo per tonne/kilometer for the first 100 kilometers, 6 kobo per kilometer for the next 101-250 kilometers, and 5 kobo per kilometer for distances over 250 kilometers,(1 kobo = 1.6 cents (U.S.A.) and 100

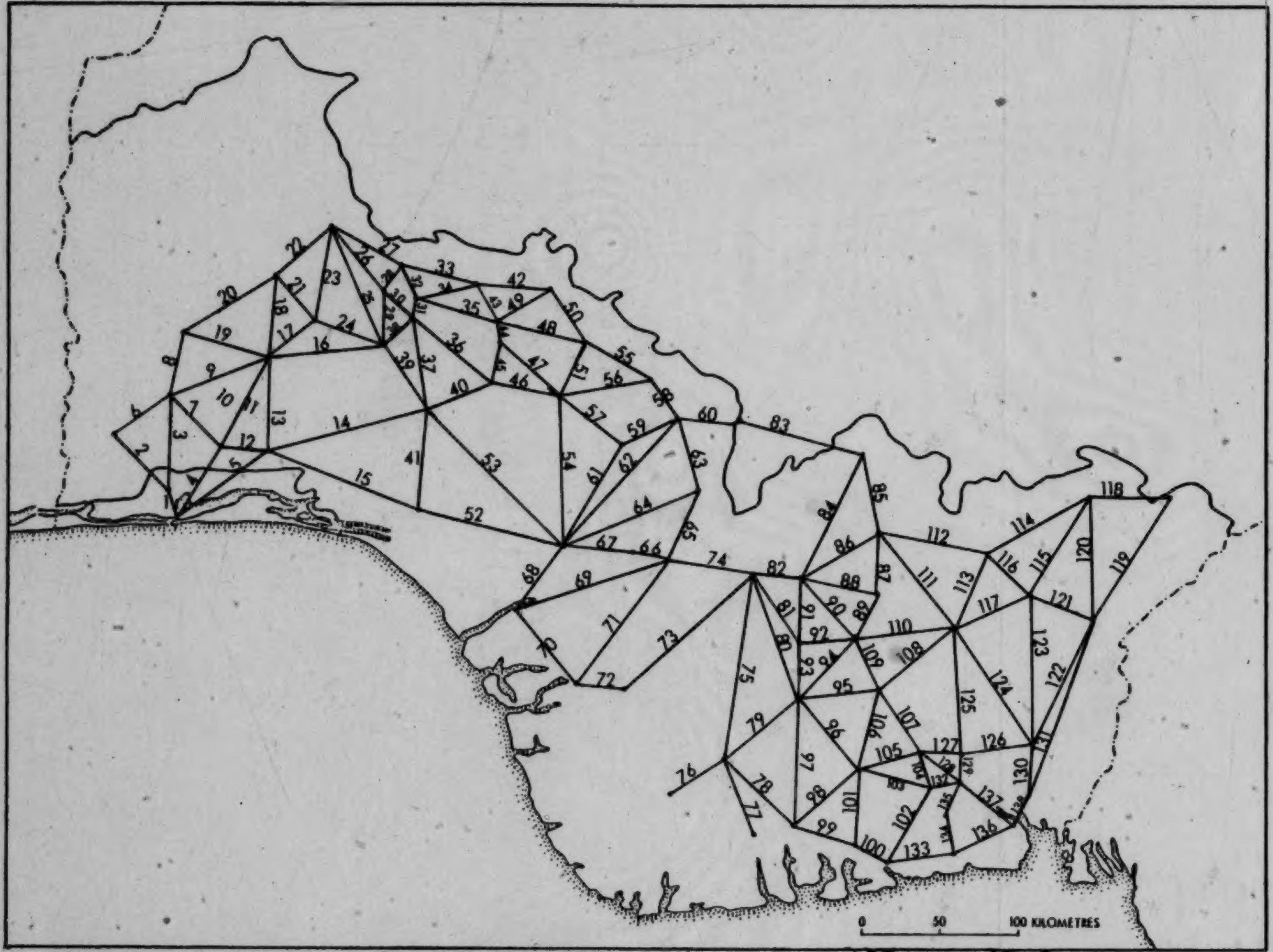

0
50
100 KILOMETRES

FIGURE 18 THE ROAD TRANSPORT NETWORK IN THE AREA OF STUDY

kobo = N1.00). The same rates apply to both cocoa and palm kernels.

For example : Suppose that the distance from an origin to a destination is 500 kilometers, then the freight rate is calculated as follows,

1. First 100 km at 7 kobo per km = N7.00
2. Next 101 to 250 km at 6 kobo per km = N9.00
3. Next 251 to 500 km at 5 kobo per km = N12.50.

TOTAL = N28.50

The road distances of the direct links and the long-haul distances to the ports were calculated. The application of the transport freight rate differential of the Commodity Boards for obtaining the rates for these distances was straightforward and was easily caculated for all the links, both direct and long-hauls in the network. Therefore there was no need for obtaining any prediction model as was the case with the shipping freight rates of the carriers discussed below.

The impact of the lower rate for longer distances was quite effective. Both the long-haul rates and the rates on the direct links were introduced in the cost matrix and the model had the option to choose between these long-haul rates and the rates on the direct links between the nodes in the system.

5.4.3 The Freight Rates by Road as Set by the Transport Firms

5.4.3.1 Obtaining Samples of Road Transport Freight Rates

Data on road transport freight rates were obtained by sampling transport companies. Data on road transport freight rates to various major towns in Nigeria, with Lagos and Kaduna as loading points were obtained from the National Freight Transport Company. This company is owned by the Federal government of Nigeria and was established in 1977 to help in stabilizing road freight traffic rates in the country.

In addition, freight transport carriers at Ibadan, Benin, Enugu, Calabar, and Kano were sampled between May and September 1978 in order to obtain their freight transport rates between some major towns in the country. The towns in which the transport carriers were sampled are all State Administrative Headquarters and/or major ports. With the exception of Kaduna and Enugu, they are also Commodity Board Headquarters for various export commodities (Ibadan, Kano, Calabar and Benin are the headquarters of the Cocoa, Groundnuts, Palm Produce, and Rubber Boards, respectively). Therefore, a number of large transport companies operating all over the country are based in these large towns, and the freight freight rates obtained from these sample points can be considered to be fairly representative of the whole country. Fig 19 shows the location of these sample points.

The procedure that was used in sampling the transport companies was as follows ;

1. A list of State Administrative, Provincial and Divisional Headquarters and other major towns was compiled.
2. At each sample point, at least three different transport companies that operate large-scale freight transport business were interveiwed.
3. The carriers were asked to quote their transport rates for transporting a 10-tonne lorry or 25-tonne trailer from the sample point to each of the towns in the list complied. In most cases, they did not have a comprehensive list but if they had data to other major towns that were not in the list complied, these were obtained.
4. The average freight rate per tonne for each link in network for which data were obtained at each sample point was then calculated. These are shown in Appendix I.

5.4.3.2 Modelling Road Freight Transport Cost

It was not possible to obtain the exact freight rates on all the links. Out of a total of 138 direct links on the road network, the exact freight rates on 54 links were obtained. The exact freight rates on 183 long-hauls from the origins to the seaports were also obtained. This comprises

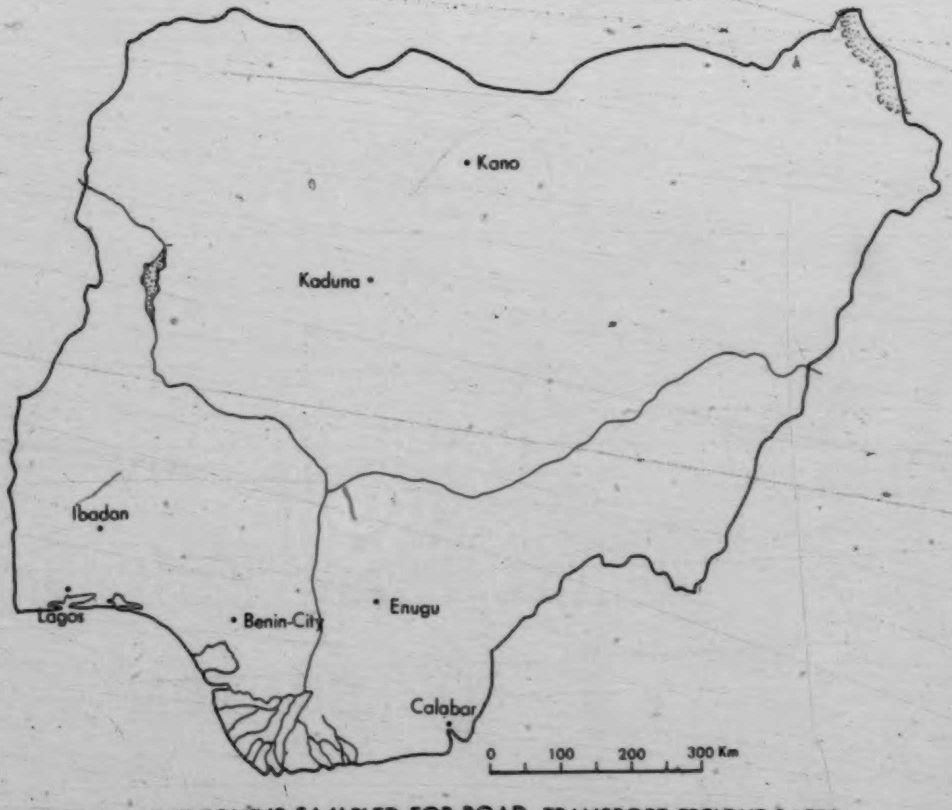

Kano
Kaduna
Ibadan
Lagos
Benin-City
Enugu
Calabar
0
100
200
300 Km

FIGURE 19. THE TOWNS SAMPLED FOR ROAD TRANSPORT FREIGHT RATES

58 percent of the total number of long-hauls from all the origins to all the ports.

Since it was not possible to obtain the exact freight rates on all links and the long-hauls, a representative model was needed for estimating the road shipping rates on the remaining direct links and long-hauls to the seaports for which freight rates were not available. A straight line trend of the form,

$Y = a + bX$

was fitted to this data, where

Y = transport cost

X = A function of distance

In order to obtain the functional form which best represents shipping rates in the area of study, the following relationships and transformations of the distance variable were investigated.

1. A simple linear relationship between transport cost and distance.
2. Squaring the distance variable.
3. Log transformation of the distance variable.
4. The Polynomial Funtion of the distance variable.

These were done in order to find out the model that is best suitable for predicting costs on the links for which exact transport costs were not available.

In addition to the transformation of the data, several aggregations of the data were investigated in order to obtain the most representative model for predicting road transport costs in the area of study. The following approach was used in investigating the best aggregation.

1. Models for individual sample points. This was done in order obtain a general impression of which relationship or transformation of the variables produced the best model at each sample point.
2. Models for the five southern sample points. Since cocoa and palm kernels are grown mostly in the southern parts of Nigeria, the models obtained from this aggregation may be more representative of the pattern of road transport freight rates for the carriers who were sampled. It may also be possible to reduce the differences in the different samples in this way.
3. All Seven Sample Points. This approach was investigated in order to see if it would improve on the models obtained from the previous aggregation of sample points in the south. Since it includes samples for the whole country, it may be more representative of the freight rates by the carriers.

Models Obtained for the Individual Sample Points

The scattergrams obtained for each of the sample points indicate that there exists a positive linear relationship between these costs and distance. Figs. 20 and 21 show that the data for Kaduna and Lagos are strictly linear. This is because the National Freight Transport Company bases it transport rates strictly on distance. They operate mostly

FIGURE 20. SCATTERGRAM OF DISTANCE VERSUS COST FOR LAGOS SAMPLE

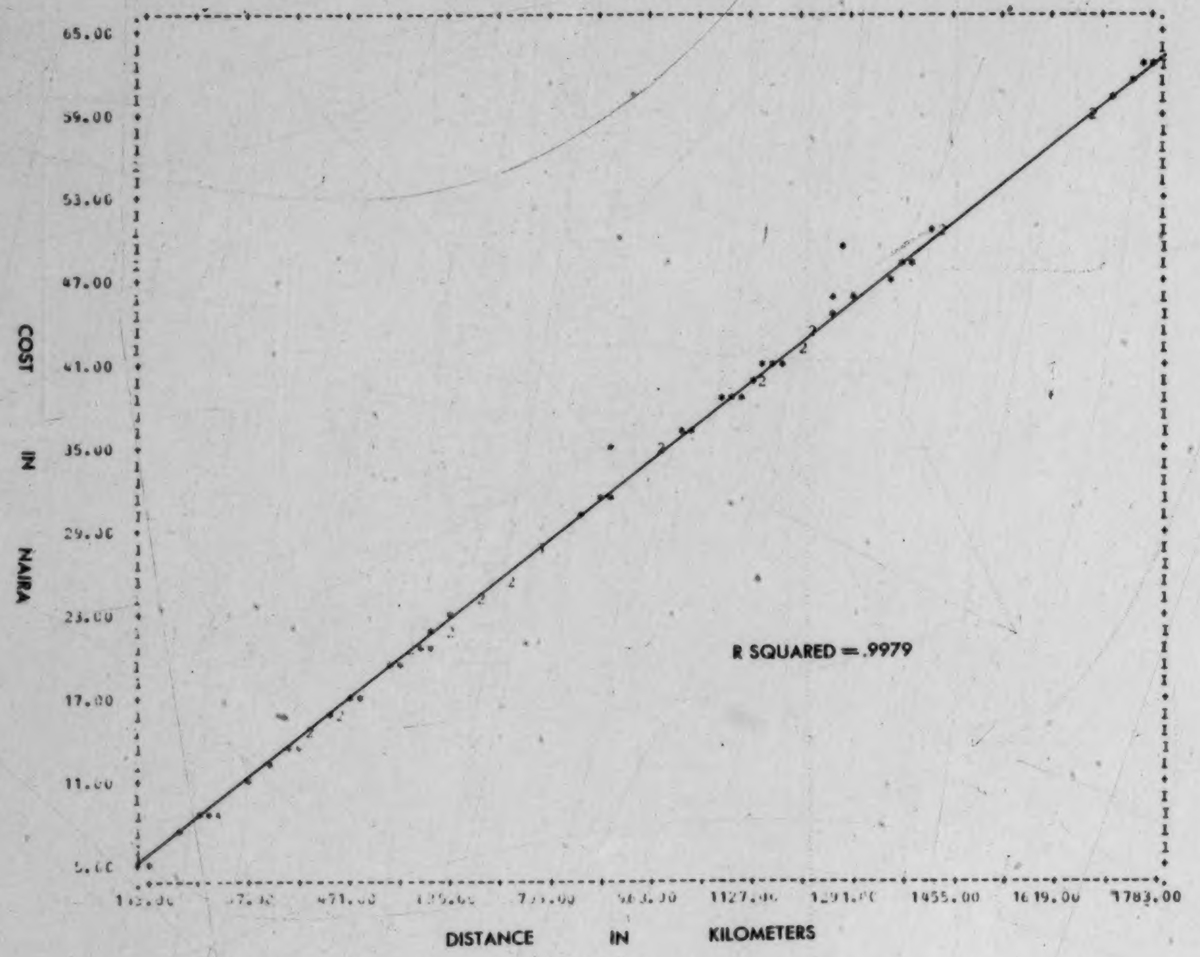
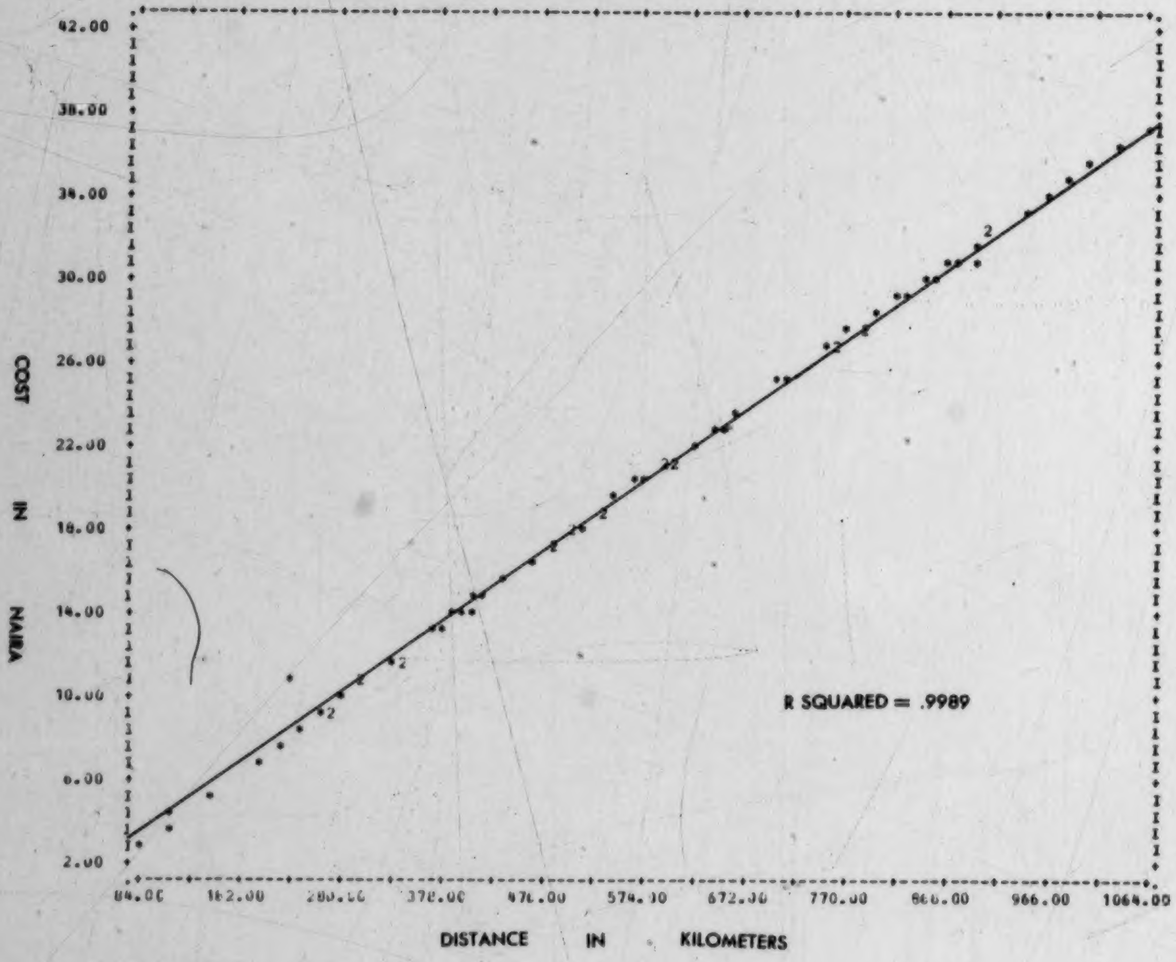


FIGURE 21. SCATTERGRAM OF DISTANCE VERSUS COST FOR KADUNA SAMPLE



25-30 tonnne trailers which are less costly to operate and also more economical to maintain than the 10-tonne trucks. Their rates are deliberately set lower than those of other carriers.

Figures 22 and 23 show that there is a tendency to underpredict short trips at Enugu and Benin and overpredict long trips as well from Benin. Figure 24 indicates that the Calabar model predicts short and long distances fairly well but underpredicts trips of moderate distances. Figure 25 shows that the transport costs for trips made to average distances from Ibadan are overpredicted while the costs for some of the trips involving long distances are underpredicted. Figure 26 illustrates that the Kano model involves mostly very long distances due to its northern location.

The overprediction of costs for long distances can be explained by the fact that usually the road transport carriers sampled do not make regular trips to these long distances. If such trips are made, it is usually because of a strong attraction for return loads and so their rates tend to be overestimated by the carriers who were sampled.

The regression statistics obtained for the individual sample point models are shown in Tables 7 to 13. Squaring and log transformation of the distance variable did not raise the level of statistical explanation

FIGURE 22. SCATTERGRAM OF DISTANCE VERSUS COST FOR ENUGU SAMPLE

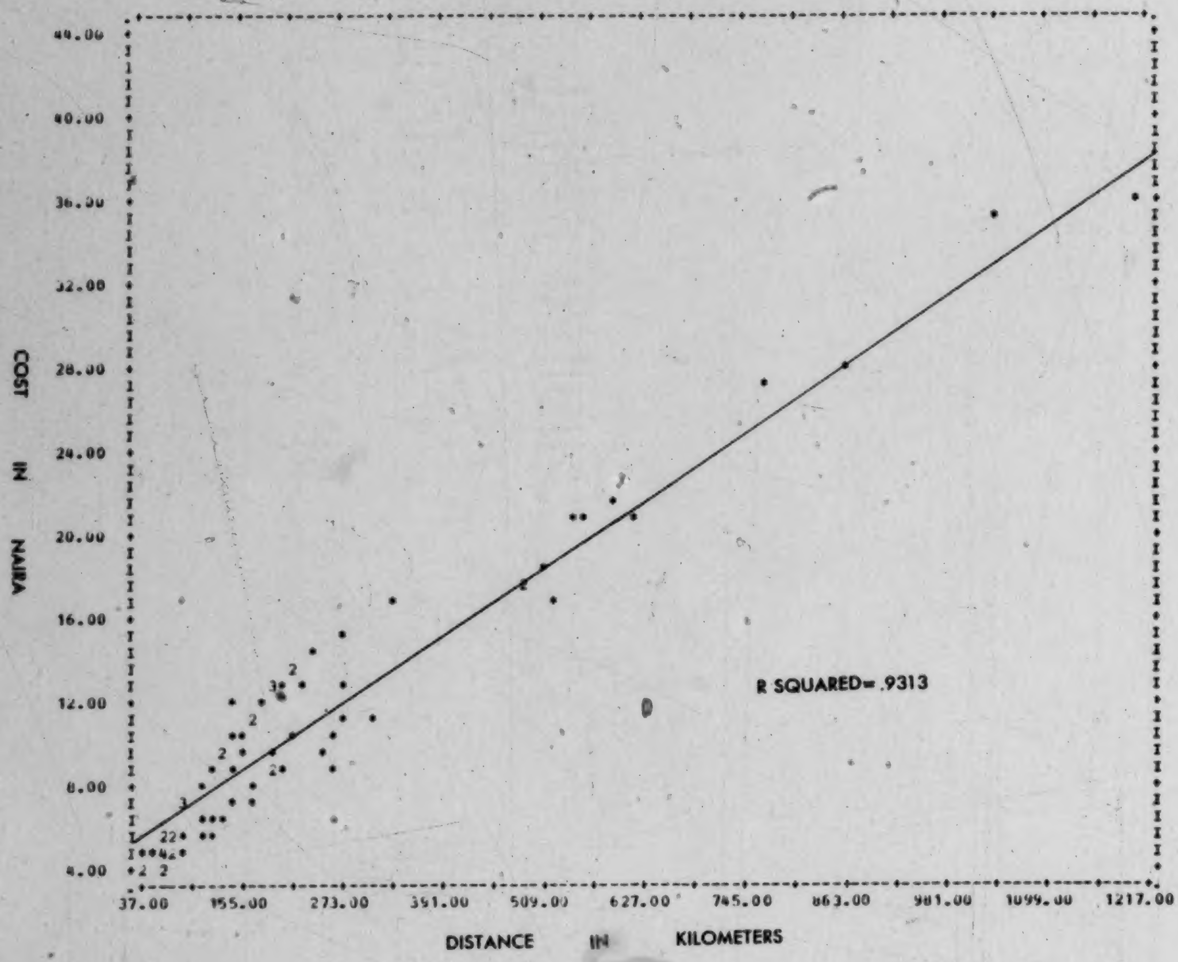


FIGURE 23. SCATTERGRAM OF DISTANCE VERSUS COST FOR BENIN SAMPLE

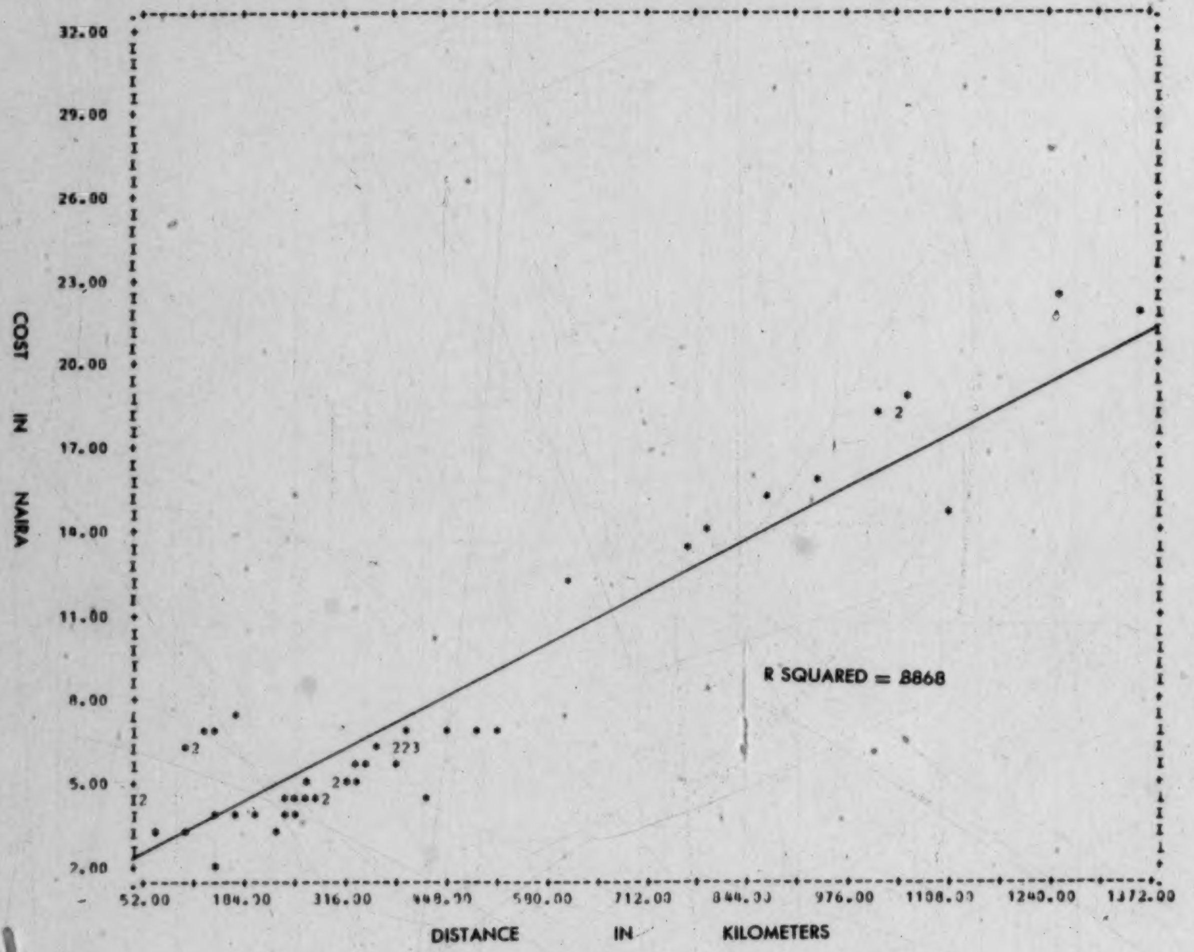


FIGURE 24. SCATTERGRAM OF DISTANCE VERSUS COST FOR CALABAR SAMPLE

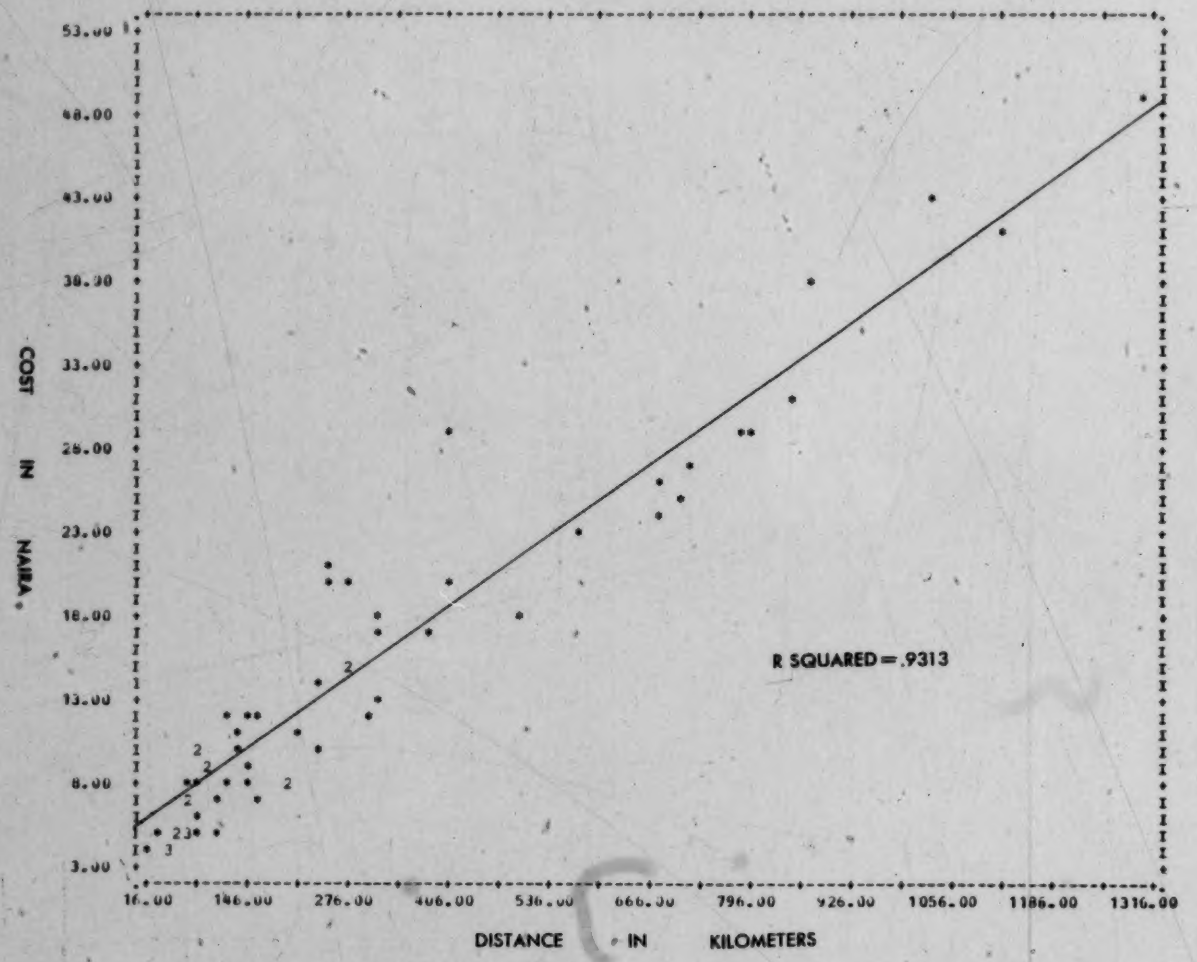


FIGURE 25. SCATTERGRAM OF DISTANCE VERSUS COST FOR IBADAN SAMPLE

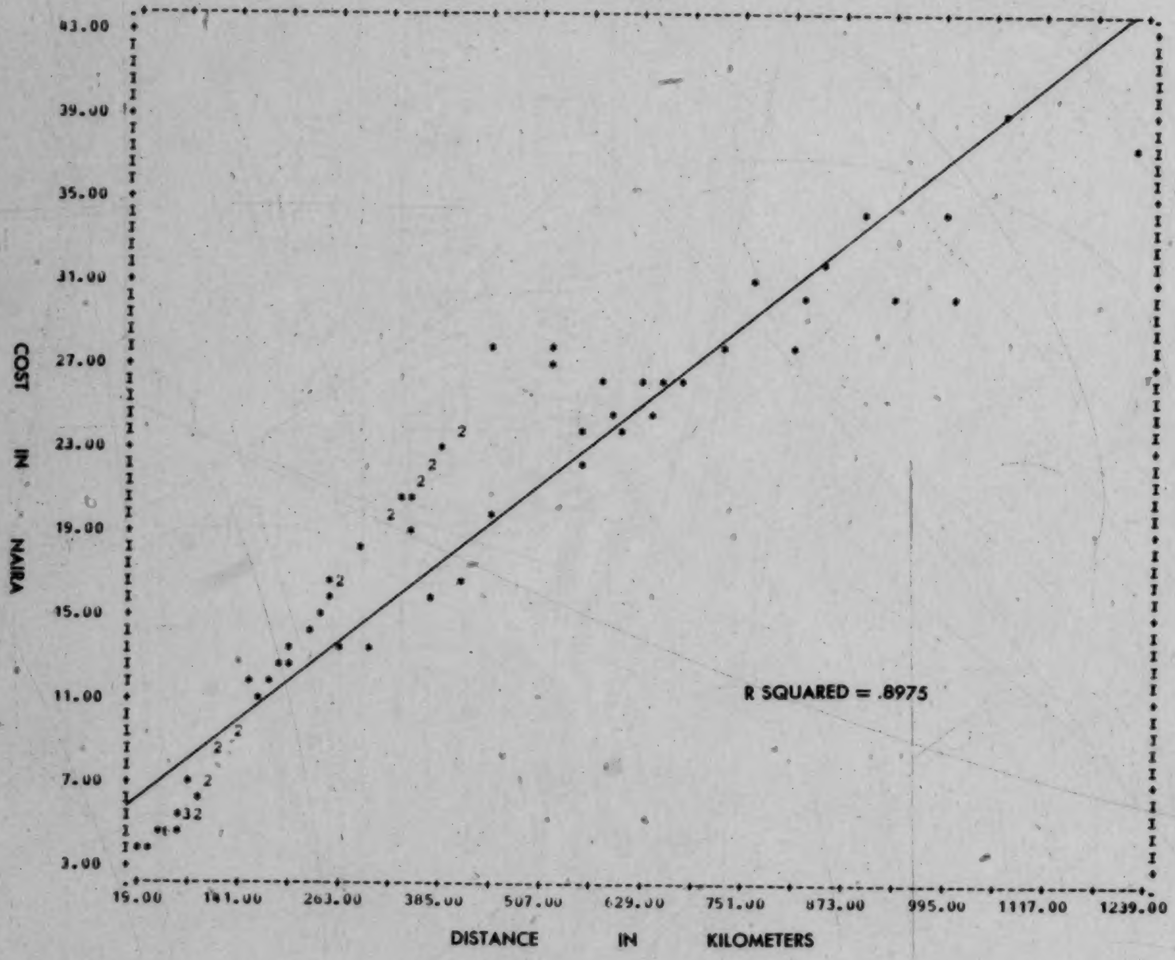


FIGURE 26. SCATTERGRAM OF DISTANCE VERSUS COST FOR KANO SAMPLE

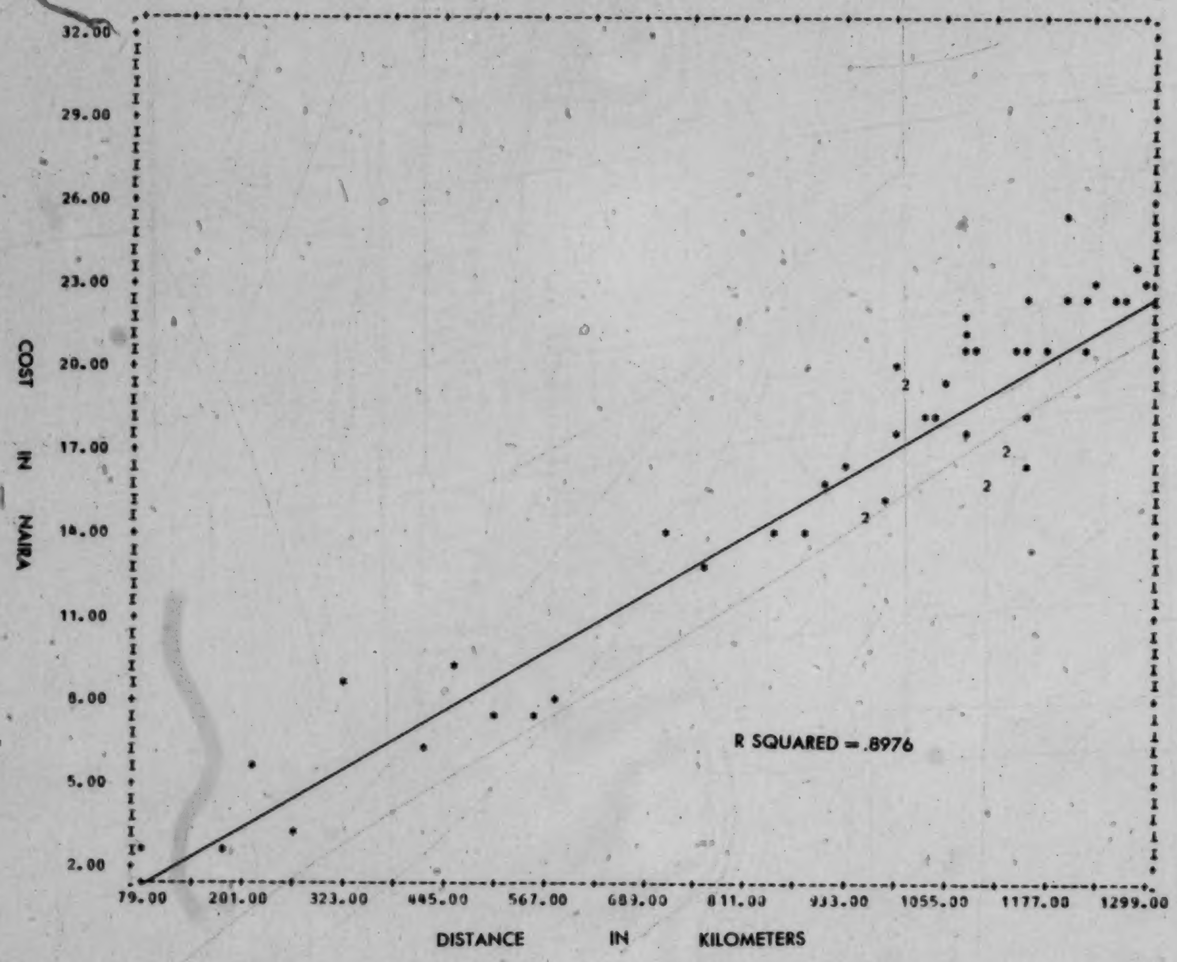


TABLE 7. LAGOS REGRESSION MODELS

```
                                                          2
1. Multiple R=.9990  F(1,68)=32771. *=.0005   R = .9979
   =====================================================
    Variables         b          F(1,68)          *
   =====================================================
    DISTANCE       .0354       32771.           .0005
   =====================================================
    CONSTANT -.029
```

```
                                                          2
2. Multiple R=.9713  F(1,68)=1132. *=.0005   R = .9434
   =====================================================
    Variables         b          F(1,68)          *
   =====================================================
              2
   (DISTANCE)     .000018       1132.            .0005
   =====================================================
    CONSTANT 14.2
```

```
                                                          2
3. Multiple R=.9549  F(1,68)=702.9 *=.0005   R   = .9118
   =====================================================
    Variables         b          F(1,68)          *
   =====================================================
   LOG10(DISTANCE)   58.3       702.9            .0005
   =====================================================
    CONSTANT   -136.7
```

```
                                                          2
4. Multiple R=.9990  F(2,67)=16349. *=.0005   R = .9979
   =====================================================
     Variables        b          F(1,67)          *
   =====================================================
   DISTANCE        .0362        1788.           .0005
             2
   DISTANCE     -.0000002        .849           NOT SIG
   =====================================================
    CONSTANT   -.315
```

TABLE 8. KADUNA REGRESSION MODELS

```
                                                                2
1.  Multiple R=.9995  F(1,67)=61070.   *=.0005  R =.9989
    ===================================================
    Variables           b           F(1,67)          *
    ===================================================
    DISTANCE         .0349         61070.         .0005
    ===================================================
    CONSTANT    .169


                                                             2
2.  Multiple R=.9768  F(1,67)=1132.  *=.0005   R =.9542
    ===================================================
    Variables            b          F(1,67)          *
    ===================================================
                 2
    (DISTANCE)        .000029        1397.        .0005
    ===================================================
    CONSTANT    8.76


                                                                2
3.  Multiple R=.9516  F(1,67)=642.     *=.0005   R =.9055
    ===================================================
    Variables            b            F(1,67)          *
    ===================================================
    LOG 10(DISTANCE)  34.9            642.          .0005
    ===================================================
    CONSTANT   -73.9


                                                             2
4.  Multiple R=.9995  F(2,66)=30181.  *=.0005  R =.9989
    ===================================================
    Variables            b            F(1,66)          *
    ===================================================
    DISTANCE          .0347          2700.          .0005
             2
    DISTANCE      .000000267         .224          NOT SIG
    ===================================================
    CONSTANT  .239
```

TABLE 9. ENUGU REGRESSION MODELS

1. Multiple R=.9651 F(1,72)=976.4 *=.0005 R^2 =.9313

Variables	b	F(1,72)	*
DISTANCE	.0284	976.4	.0005
CONSTANT 4.36			

2. Multiple R=.8901 F(1,72)=274.5 *=.0005 R^2 =.7922

Variables	b	F(1,72)	*
$(\text{DISTANCE})^2$	.000025	274.5	.0005
CONSTANT 8.28			

3. Multiple R=.9087 F(1,72)=340.9 *=.0005 R^2 =.8256

Variables	b	F(1,72)	*
LOG 10(DISTANCE)	17.4	340.9	.0005
CONSTANT -27.6			

4. Multiple R=.9673 F(2,71)=515.7 *=.0005 R^2 =.9356

Variables	b	F(1,72)	*
DISTANCE	.0339	158.1	.0005
DISTANCE^2	-.00000567	4.71	.05
CONSTANT 3.67			

TABLE 10. CALABAR REGRESSION MODELS

```
                                                           2
1. Multiple R=.9650  F(1,59)=799.8   *=.0005     R =.9313
   ==================================================================
   Variables              b             F(1,59)            *
   ==================================================================
   DISTANCE            .0339           799.9             .0005
   ==================================================================
   CONSTANT  4.52
```

```
                                                           2
2.  Multiple R=.9123  F(1,59)=292.8   *=.0005    R =.8323
    =================================================================
    Variables           b               F(1,59)            *
    =================================================================
               2
    (DISTANCE)      .000029          292.8              .0005
    =================================================================
    CONSTANT  9.4
```

```
                                                           2
3.  Multiple R=.8904  F(1,59)=225.7   *=.0005     R =.7928
    =================================================================
    Variables               b           F(1,59)            *
    =================================================================
    LOG 10(DISTANCE)      21.4          225.7              .0005
    =================================================================
    CONSTANT  -33.8
```

```
                                                           2
4.  Multiple R=.9654  F(2,58)=398.    *=.0005     R =.9321
    =================================================================
    Variables               b           F(1,58)            *
    =================================================================
    DISTANCE              .037           85.2              .0005
               2
    DISTANCE     -.00000296              .66             NOT SIG
    =================================================================
    CONSTANT 4.13
```

TABLE 11. BENIN REGRESSION MODELS

```
                                                        2
1. Multiple R=.9417  F(1,54)=423.1   *=.0005      R =.8868
   ===========================================================
   Variables          b            F(1,54)           *
   ===========================================================
   DISTANCE        .0149           423.1           .0005
   ===========================================================
   CONSTANT   1.36


                                                         2
2. Multiple R=.9566   F(1,54)=581.9   *=.0005      R =.9151
   ===========================================================
   Variables         b             F(1,54)            *
   ===========================================================
               2
   (DISTANCE)     .000012          581.9           .0005
   ===========================================================
   CONSTANT   4.37


                                                        2
3. Multiple R=.7706  F(1,54)=78.9    *=.0005      R =.5938
   ===========================================================
   Variables             b         F(1,54)           *
   ===========================================================
   LOG 10(DISTANCE)  11.8          78.9            .0005
   ===========================================================
   CONSTANT   -21.8


                                                        2
4. Multiple R=.9586  F(2,53)=300.2   *=.0005      R =.9189
   ===========================================================
   Variables             b         F(1,53)           *
   ===========================================================
   DISTANCE          .0039          2.49              .25
              2
   DISTANCE    .00000866           20.9              .0005
   ===========================================================
   CONSTANT   3.54
```

TABLE 12. IBADAN REGRESSION MODELS

1. Multiple R=.9473 F(1,75)=656.4 *=.0005 R^2 =.8975

Variables	b	F(1,75)	*
DISTANCE	.000026	656.4	.0005
CONSTANT 11.6			

2. Multiple R=.8306 F(1,75)=166.8 *=.0005 R^2 =.6899

Variables	b	F(1,75)	*
$(\text{DISTANCE})^2$	.000026	166.8	.0005
CONSTANT 11.6			

3. Multiple R=.9556 F(1,75)=788.9 *=.0005 R^2 =.9132

Variables	b	F(1,75)	*
LOG 10(DISTANCE)	.9556	788.9	.0005
CONSTANT -34.5			

4. Multiple R=.9756 F(2,74)=782.2 *=.0005 R^2 =.9517

Variables	b	F(1,74)	*
DISTANCE	.0551	401.2	.0005
DISTANCE^2	-.0000239	83.1	.0005
CONSTANT 2.35			

TABLE 13. KANO REGRESSION MODELS

```
                                                           2
1. Multiple R=.9474  F(1,48)=420.8   *=.0005  R =.8972
   ============================================================
   Variables           b          F(1,48)            *
   ============================================================
   DISTANCE         .0175        420.8             .0005
   ============================================================
   CONSTANT  .0192


                                                          2
2. Multiple R=.9411  F(1,48)=371.5  *=0005    R =.8856
   ============================================================
   Variables            b          F(1,48)            *
   ============================================================
              2
   (DISTANCE)       .000012      371.5             .0005
   ============================================================
   CONSTANT  5.12


                                                         2
3. Multiple R=.8855  F(1,48)=174.3  *=.0005  R =.7841
   ============================================================
   Variables            b          F(1,48)            *
   ============================================================
   LOG 10(DISTANCE)   20.9        174.3             .0005
   ============================================================
   CONSTANT  -44.8


                                                         2
4. Multiple R=.9496  F(2,47)=791.4  *=.0005  R =.9017
   ============================================================
   Variables            b          F(1,47)            *
   ============================================================
   DISTANCE           .0117        7.70              .01
              2
   DISTANCE      .00000389         1.95            NOT SIG
   ============================================================
   CONSTANT  1.60
```

for Lagos, Kaduna, Calabar, Enugu, Ibadan and Kano sample points while this transformation improved the model for the Benin sample. While the logarithmic transformation of the distance variable performed better than the squaring of the same variable in the Ibadan and Enugu samples, the reverse was the case for the Benin sample. Whereas the model obtained from the polynomial function of the distance variable only slightly raised the level of statistical explanation for Benin and and Ibadan sample points, it had no effect on the models obtained for Lagos and Kaduna samples. It slightly raised the level of explanation for Enugu, Calabar and Kano samples but the square of the distance variable was not statistically significant in these models. This indicates that the simple linear form of distance explains the freight rates in these sample points so well that the introduction of other transformations of this variable do not improve the models.

Southern Sample Points

All the five sample points in the south namely, Lagos, Ibadan, Benin, Enugu and Calabar were modelled together since cocoa and palm kernels are grown mostly in southern Nigeria. The scattergram for this aggregation (Figure 27) indicates that there are two distinct bands in the pattern. Also, the tendency to to overpredict long trips and underpredict short trips was still observed.

Table 14 shows the results of the regression models

FIGURE 27. SCATTERGRAM OF DISTANCE VERSUS COST FOR THE FIVE SOUTHERN SAMPLE POINTS

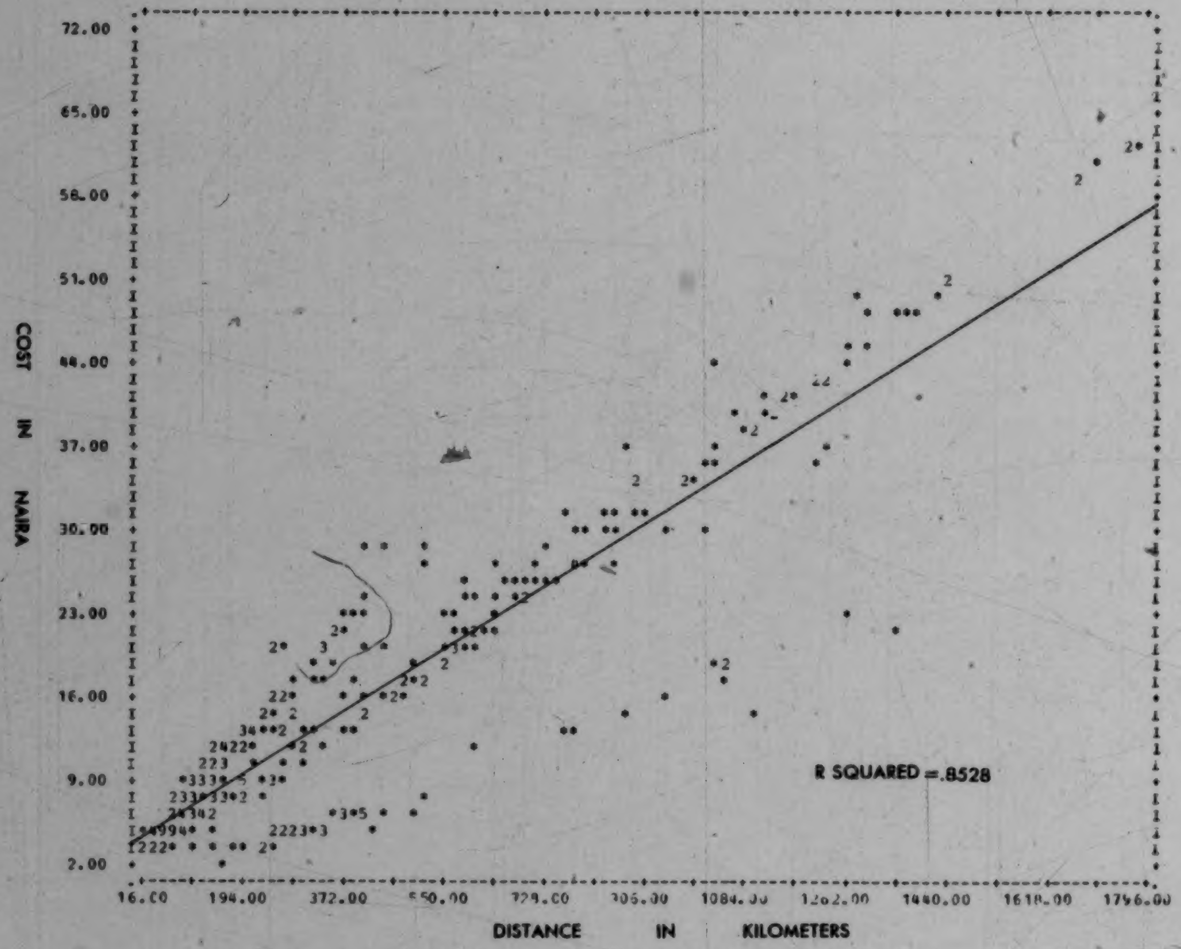


TABLE 14. FIVE SOUTHERN SAMPLE POINTS REGRESSION MODELS

```
                                                          2
1. Multiple R=.9241  F(1,328)=1917.  *=.0005         R =.8539
   ==============================================================
   Variables             b          F(1,328)            *
   ==============================================================
   DISTANCE           .0303        1917.            .0005
   ==============================================================
   CONSTANT  3.26


                                                          2
2. Multiple R=.8955  F(1,328)=1328.  *=.0005         R =.8020
   ==============================================================
   Variables             b          F(1,328)            *
   ==============================================================
             2
   (DISTANCE)       .00002         1328.            .0005
   ==============================================================
   CONSTANT  9.52


                                                          2
3. Multiple R=.8160  F(1,328)=653.8    *=.0005       R =.6669
   ==============================================================
   Variables             b            F(1,328)             *
   ==============================================================
   LOG 10(DISTANCE)    24.4          653.8             .0005
   ==============================================================
   CONSTANT  -43.1


                                                          2
4. Multiple R=.9257  F(2,327)=979.5    *=.0005       R =.8569
   ==============================================================
   Variables             b            F(1,327)             *
   ==============================================================
   DISTANCE            .0248          125.7              .0005
            2
   DISTANCE      .00000400            6.93               .01
   ==============================================================
   CONSTANT  4.29
```

obtained for the southern sample points. Log transformation and squaring of the distance variable did not improve the models for this aggregation. The best model was obtained from the simple linear relationship between cost and distance. This model performed better than the other two models when the observed values were plotted against the values predicted from these models (Figure 28). The other models grossly underpredicted costs, and are not presented.

All Sample Points Modelled Together

All seven sample points in the country were then modelled together. Figure 29 shows that the tendency to have two distinct bands is more pronounced in this model. Table 15 shows the results of the regression models obtained from this aggregation. Log transformation and squaring of the distance variable did not improve the models. As in the former aggregation, the best model was obtained from the simple relationship between cost and distance. This model (Figure 30), performed better than the other two which are not presented, when the observed values were plotted against the values predicted from the models.

Choice of Model Used for Prediction

The models indicate that the simple linear relationship between cost and distance is generally so strong that further transformation of the distance variable did not improve the models. A further attempt to improve the models

FIGURE 28. OBSERVED VERSUS PREDICTED VALUES FOR THE FIVE SOUTHERN SAMPLE POINTS

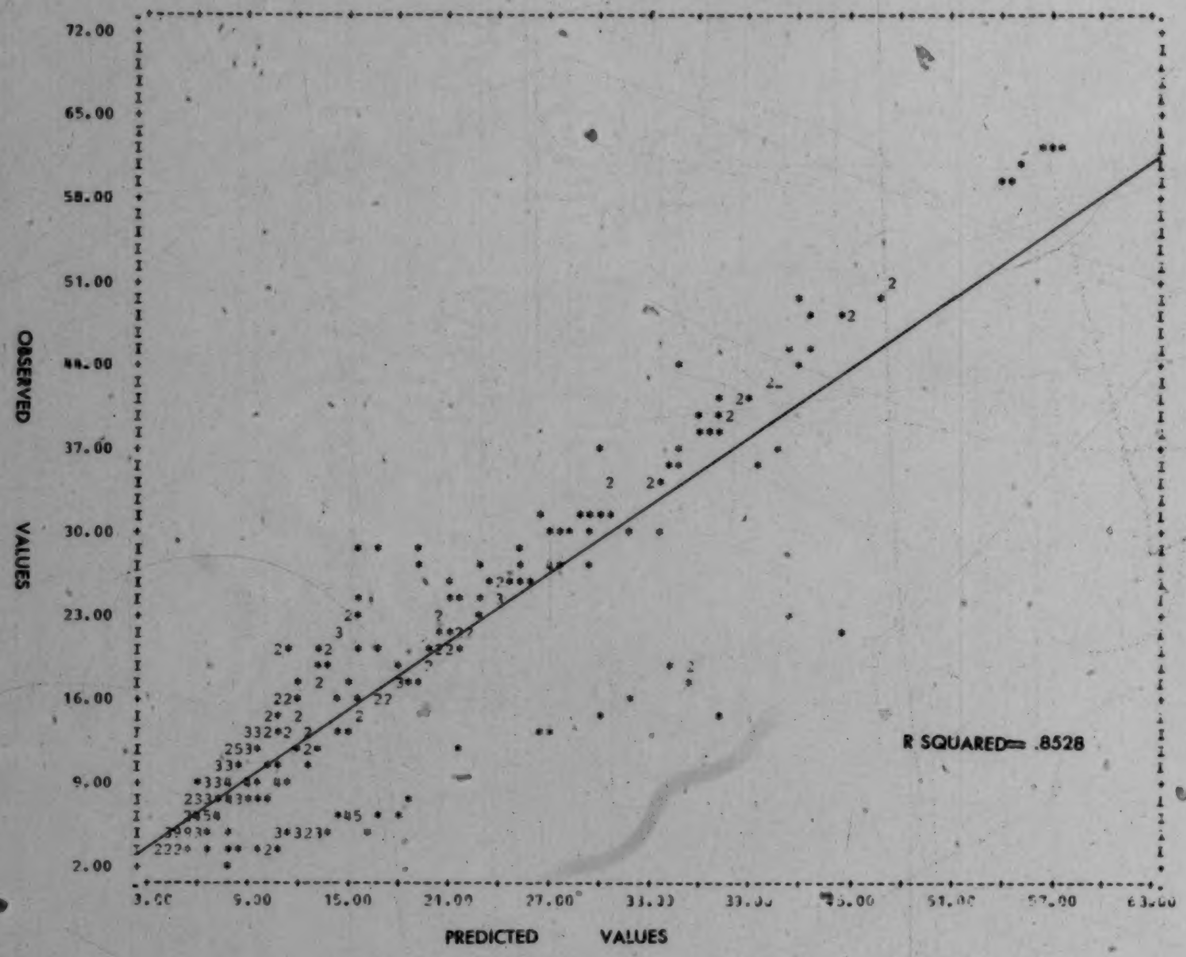


FIGURE 29. SCATTERGRAM OF DISTANCE VERSUS COST FOR ALL SAMPLE POINTS

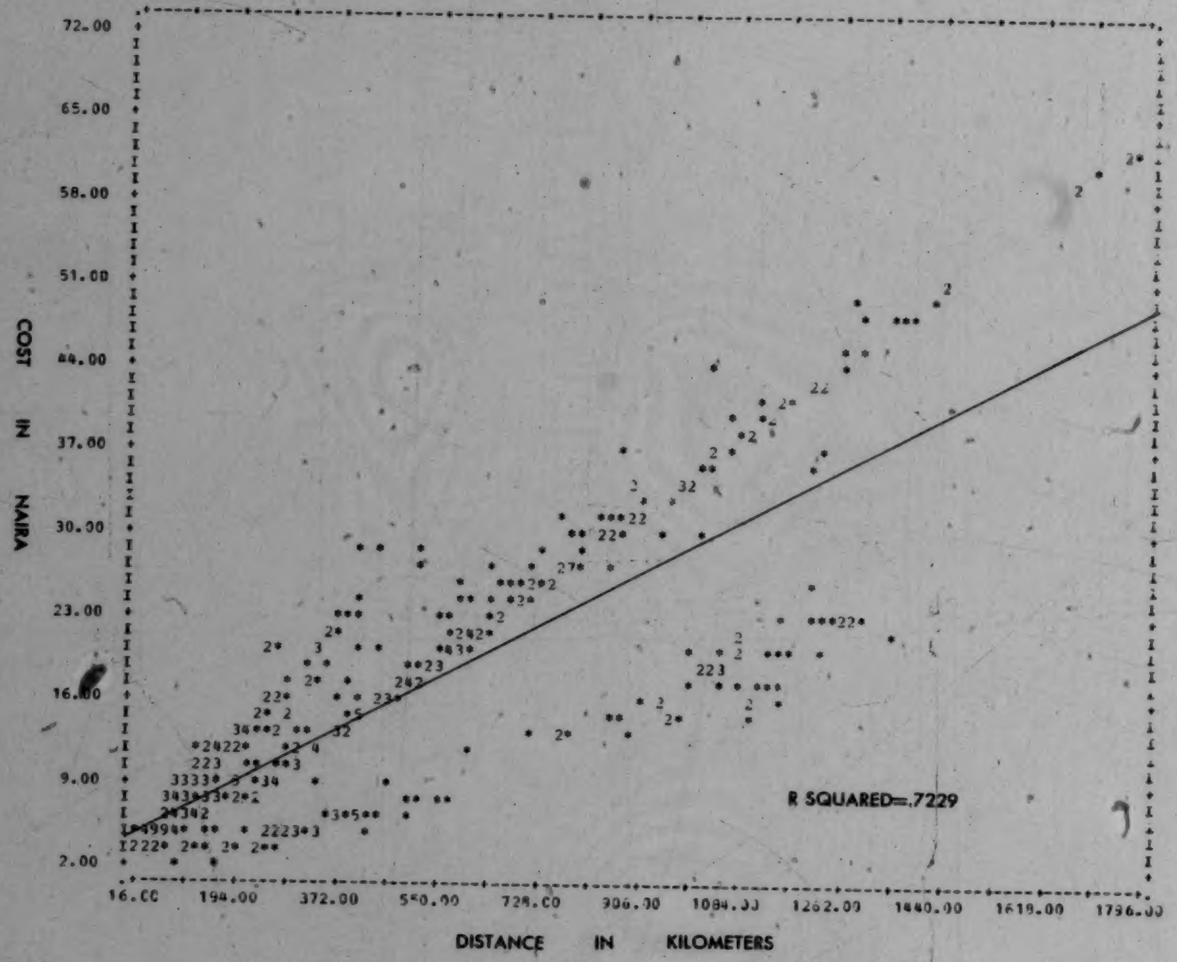


TABLE 15. ALL SEVEN SAMPLE POINTS REGRESSION MODELS

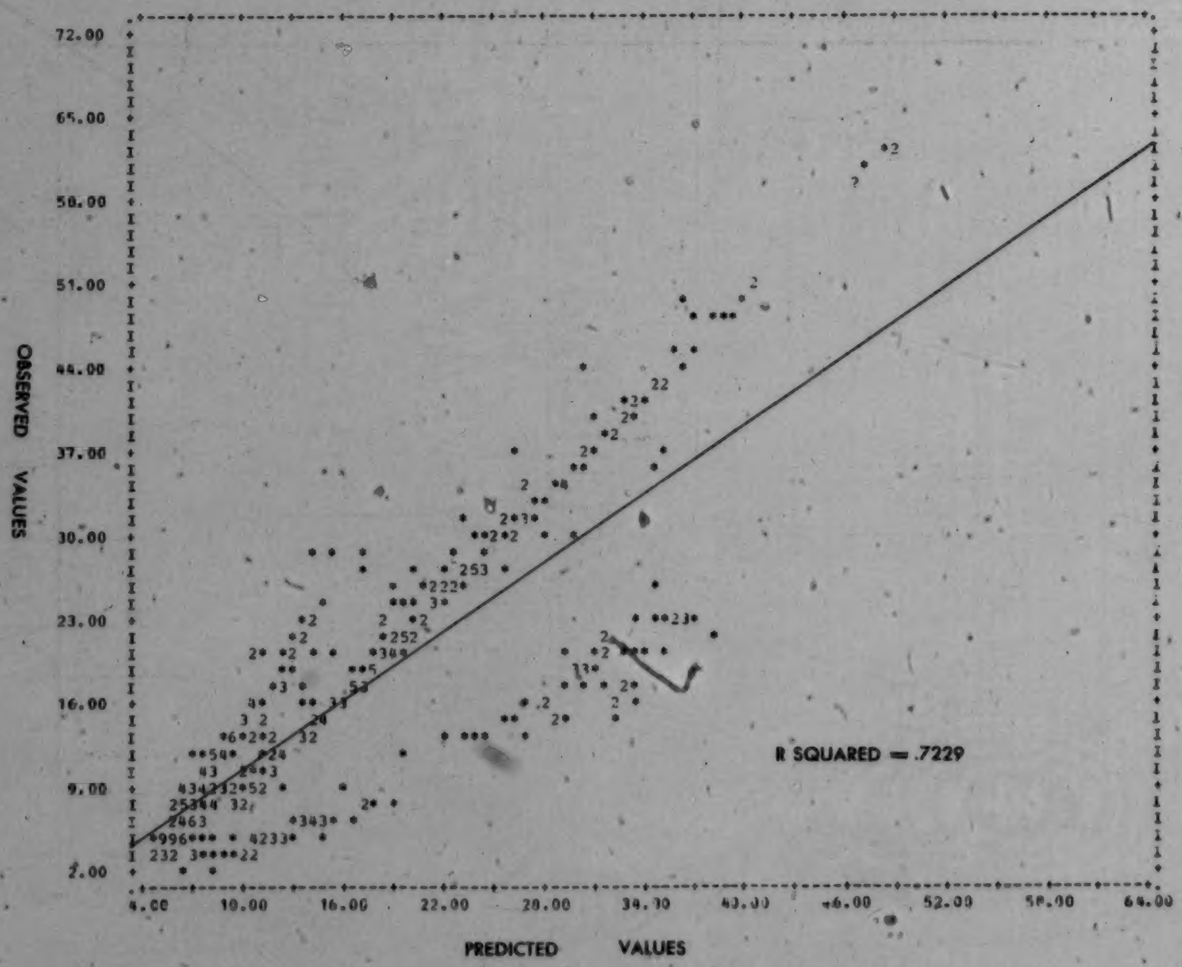
```
                                                              2
1. Multiple R=.8502  F(1,447)=1165.    *=.0005    R =.7229
   ==========================================================
   Variables         b            F(1,447)            *
   ==========================================================
   DISTANCE       .0253            1166.          .0005
   ==========================================================
   CONSTANT   4.17


                                                              2
2. Multiple R=.8301  F(1,447)=990.8     *=.0005   R =.6891
   ==========================================================
   Variables         b            F(1,447)            *
   ==========================================================
              2
   (DISTANCE)    .000017          990.8           .0005
   ==========================================================
   CONSTANT   9.7


                                                              2
3. Multiple R=.7721  F(1,447)=659.6     *=.0005   R =.5961
   ==========================================================
   Variable             b         F(1,447)            *
   ==========================================================
   LOG 10(DISTANCE)  21.7          1166.          .0005
   ==========================================================
   CONSTANT    -37.8


                                                              2
4. Multiple R=.8524  F(2,446)=592.6     *=.0005   R =.7266
   ==========================================================
   Variables            b          F(1,446)           *
   ==========================================================
   DISTANCE          .0194          61.1            .0005
           2
   DISTANCE     .00000432           6.10            .025
   ==========================================================
   CONSTANT   5.33
```

FIGURE 30. OBSERVED VERSUS PREDICTED VALUES FOR ALL THE SAMPLE POINTS



was made by employing dummy variables for the various locations indicating whether these locations were in the northern or southern parts of the country or whether they were ports. This approach was not very successful.

The only effect it had was to reduce the prominence of the distinct bands that formerly appeared in the aggregation for all sample points when the observed values were plotted against the values predicted from the model. This is not surprising because the use of dummy varables enabled the model to take into account the general pattern of the transport costs of these carriers who operate mostly on a national scale. The amount of variation explained by this model was not significantly higher than that explained by the simple linear form of distance, however. The use of other variables related to the socio-economic characteristics of these might have been more appropriate. It was not possible to investigate these because data on such variables were not available.

The model obtained from a simple linear relationship between cost and distance is the best model in both the southern sample points aggregation and the aggregation for the whole country. The fact that cocoa and palm kernels for which costs are being estimated are grown mostly in the southern parts of the country must be taken into consideration. The model obtained from modelling all the sample points together may be more suitable for predicting long-haul costs on a national level but may be inadequate for predicting the transport costs of shipping these commodities which are grown mostly in the southern parts of the country. This is because, as has already been mentioned, long-distance trips are usually made because of a strong attraction for return loads and so their rates tend to be overestimated by carriers. If the model obtained from modelling all the sample points together is employed in prediction, this may have some adverse effects. Therefore, the model obtained from the southern sample points aggregation which has the best overall fit was considered to be the most adequate model for predicting costs on those links for which the exact cost data were not available. This simple linear model is as follows:

Freight Rate = 3.28 + .0304 (Distance)

5.4.4 Railway Transport Cost Data

The portion of the Nigerian Railway Network that lies within the study area consists of the Western and Eastern Railway Districts which terminate at Lagos and Port Harcourt ports, respectively. Since these are in the southern part of the country, the actual distances involved are very short and the longest distance by rail is less than 300 kilometers.

Data on the freight rates by rail were obtained from the Nigerian Railway Corporation. These costs were contained in the Rates and Tariff Circular (Tariff No. 8) published by the Corporation. This circular contains the rail freight rates for all railway links in the country, therefore all rail costs were obtained from this source and there was no need for developing models to be used for predicting rail freight rates.

Export commodities were classified as Class C goods and the corresponding transport rates per tonne for specific distances were used. A total of 10 direct connections on the railway were employed (Figure 31). In addition, the long-hauls from each railway node to the ports were also employed in the analysis. The long-haul rates on the railway are less expensive than the costs on the direct links because the high terminal costs on the railway have less impact on the rates of the long-haul shipments.

5.4.5 Waterway Transport Cost Data

The part of the River Niger that lies within the area of study is south of Idah. The data on the freight rate by waterway were obtained from the Central Water Transportation Company, the only company that offers water transportation services on a large scale on the River Niger. The Rivers State Marketing Board was the source of the waterway freight rate between Degema and Port Harcourt because this is the major mode of transport between these places. A total of 6 waterway links were obtained (Figure 31). All the long-haul rates on the waterway were obtained. In most cases, the freight rate data on the direct links were not available, but they were estimated from the long-haul rates on the

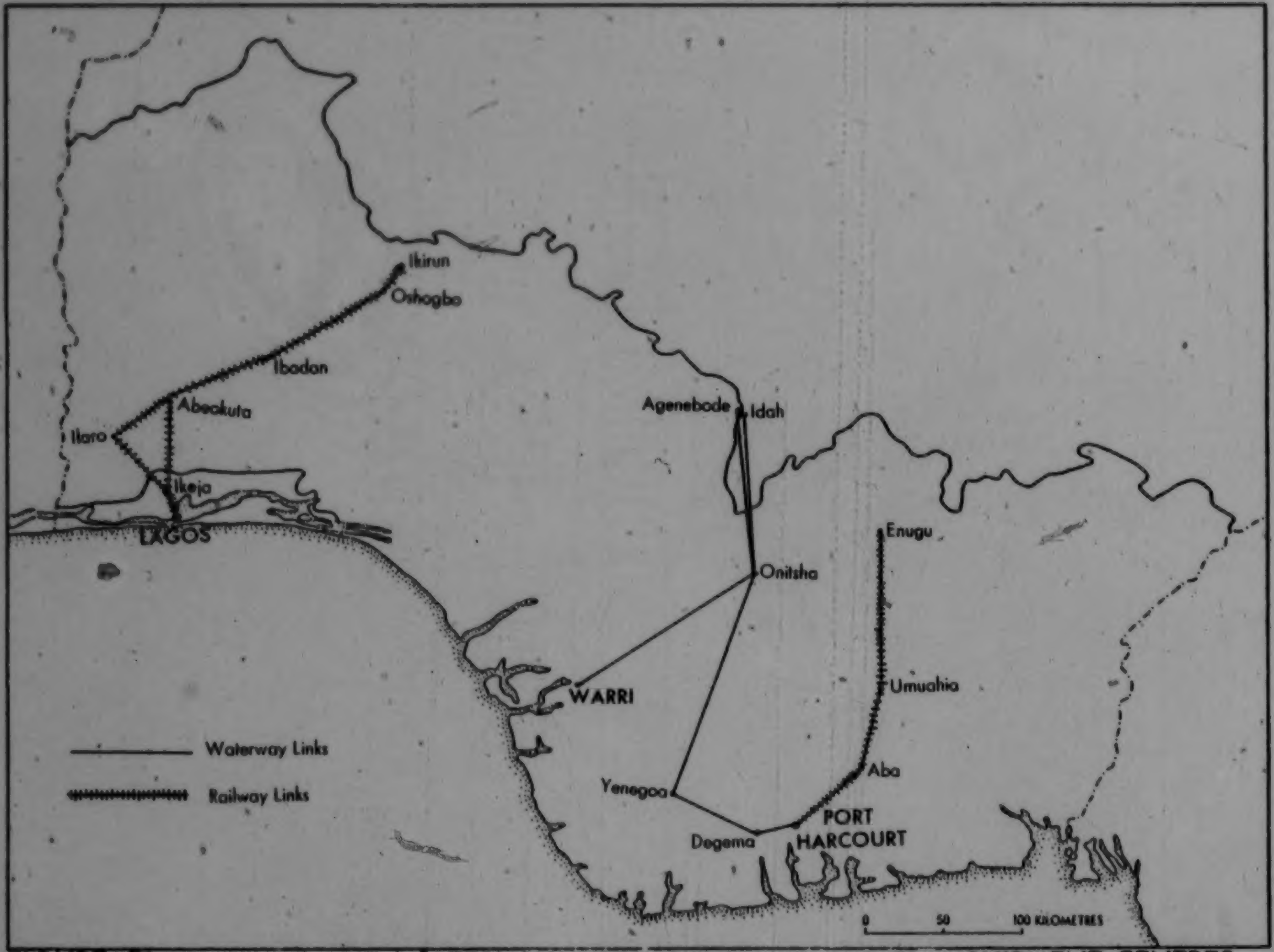

Ikirun
Oshogbo
Ibadan
Abeokuta
Ilaro
Ikeja
LAGOS
Agenebode
Idah
Onitsha
Enugu
WARRI
Umuahia
Aba
Yenegoa
PORT HARCOURT
Degema
Waterway Links
Railway Links
0
50
100 KILOMETRES

FIGURE 31 RAILWAY AND WATERWAY NETWORKS AND THE TRANSHIPMENT CENTRES

basis of nautical mileage data.

5.4.6 Transhipment Cost Data

The transhipment points are those centres served by more than one mode of transportation (Figure 31). It is assumed that each transhipment point has a different node for each mode. If the node is a port, it has an additional node. This formulation enables the cost of transhipment between all the modes in the centre to be calculated.

There is a modern bridge at Onitsha over the River Niger connecting Anambra and Bendel States, therefore, Onitsha was treated as a transhipment center for road and waterway transportation. Further north, Agenebode and Idah were treated as transhipment points because these two towns are not linked by a bridge and so are considered as transhipment points on either bank of the Niger. Both towns were linked by the appropriate transportation cost by waterway.

The cost of transhipment involving the roads and the waterways depends largely on the availability of unskilled labour which is employed in loading or offloading the bags of cocoa or palm kernels. These two commodities are comparable in weight and are exported in the same type and size of jute bags so the same transhipment cost applies to both commodities at each center. The cost of labour for loading or offloading the produce at each grading station is the transhipment cost at that station. This is the same as the handling charges cf the Commodity Boards at the grading stations. The same rates apply to loading and offloading from the truck to the warehouse, but when a change of mode is involved, the transhipment cost is the sum of loading or unloading by the two modes of transport involved. Usually, transhipment will involve offloading into the warehouse and then reloading on the different mode.

The rates ranges from six kobo to thirteen kobo per bag of produce loaded or off-loaded. The highest cost of thirteen kobo per bag was obtained at Lagos and Ikeja. Thirteen bags of cocoa or palm kernel weigh about 1 metric tonne and this estimate was used in converting the rates which were obtained according to bags to the equivalent costs per metric tonne.

The transhipment costs for the produce involving the railways were obtained differently. Usually, when these goods are delivered at the railway stations the Nigerian Railway may undertake the loading or offloading of the bags of produce for shippers. There are labourers employed by the Railway Corporation to clear goods in the railyards at the expense of the owners of the goods. In some cases, cranes and other mechanical devices may be employed where these are available. There is a fixed cost of N1.16 per tonne for loading or offloading demanded by the railway from the shippers for this service. This is the transhipment cost by railway. The same rate applies to all the railway nodes.

All the road, rail waterway freight rates and also the transhipment costs employed in the model are shown in Appendix II.

5.5 Summary

This chapter has presented the data used in the analysis namely, the quantities of the commodities purchased (Si), the demand for the commodities at the demand points (Dj), the shipping costs for each mode of transport along both the direct links and the long-hauls and the transhipment costs (Tij). It has outlined the sources of these data and their coverage and reliability, and any modifications of these data. The application of these data in the analysis are now presented.

6. Chapter Six RESULTS OF THE ANALYSIS

6.1 Introduction

This chapter presents the results of the application of the linear programming model developed to the transportation of cocoa and palm kernels in Nigeria in 1976/77. There are various quantities of the commodities purchased by the Commodity Boards in the different regions. The ports and the processing industries within the country specify demands for these commodities. The freight rates or the cost of transporting a unit of the commodities on all available routes are given or have been estimated. The problem is to determine the pattern of transporting the commodities to the ports and the industries in such a way that the total cost involved in the shipment of of the commodities is minimized for the entire system.

The optimal pattern of shipments obtained from the linear programming model is the normative or ideal pattern that would minimize the total transportation costs incurred by the Commodity Boards under the existing freight rate structure. This minimum cost solution is efficient in the sense that the prescribed set of demands cannot be satisfied at a lower total cost. Ideally, the optimal pattern could be compared with the actual pattern in order to assess its efficiency and to indicate whether factors other than transportation costs which influence the existing pattern of flows. Unfortunately, it was not possible to investigate this relationship because data on the actual pattern of shipments were not available.

In this study, knowledge of the optimal pattern of transporting cocoa and palm kernels in Nigeria is used to indicate ways of reducing the total shipping bills incurred by the Commodity Boards in moving these commodities. The commodities are moved from the regions where they are purchased to the seaports by road, railway and waterways. The reduction of total shipping bill is consistent with the major objectives of the Commodity Boards. These objectives include satisfying the given demands for the commodities at all demand points and if possible, reducing shipping bills in order to increase their net financial surplus.

The major sources of short-run inefficiency in the spatial pattern of inland transportation of export commodities in Nigeria can be distinguished as follows:

1. Imperfect shipping patterns or inefficient linking of the producing areas for these commodities to the demand points.
2. Inefficient utilization of the various modes of transport available for shipping these commodities. This may be caused by improper selection of the most economical mode of transport.
3. Inefficiencies within the various modes which may arise from wasteful crosshauls.
4. Insufficient or excess demand for the commodities at any of the demand points. This may force higher

transportation costs to be incurred in the system. Since cocoa and palm kernels are not only demanded in the processing industries within the country but also in the foreign world market for the commodities, it is desirable to ship efficiently within the entire system. The demand dual variables (vj) are shadow prices on the shipping bills and indicate the relative benefits of altering demand capacities at these demand points.

5. The location of the actual supply regions for cocoa and palm kernels may be inefficient with regard to the location of the demand points. The supply dual variables (ui) indicate the respective suitability of a location as a supply point for these commodities. This suitability is of course, only from the standpoint of transportation costs.

It has already been indicated that the railway and the waterway freight rates are fixed and are the same for all users while the road transport freight rates are negotiable but are supplied exogenously in the model. The road transport freight rates of the carriers and the road transport differential rate of the Commodity Boards were employed in the analysis. These two possibilities of road transportation were reflected by developing two models. Cost1 Model refers to the model in which the road transport freight rates provided by the carriers have been employed. It is expected that these rates will reflect actual conditions in the freight transportation business in

Nigeria. Cost2 Model refers to the model in which the road transport differential of the Commodity Boards have been employed.

The total costs incurred in transportation by employing the two models are compared in order to find out which model would result in greater savings in the shipping bills of the Commodity Boards. The relationship between the optimal solutions obtained from these costs may indicate whether there are inefficiencies in the rates set by the Commodity Boards. The results of the comparison could form a basis for improving transport policy in Nigeria and suggest possible areas of co-operation between the Boards.

The optimal value of the objective function of a linear programming model is unique but there may be different combinations of shipments (Xij's) which yield this optimal value in the system. Thus, the solution to a linear programming problem may have other alternative flow patterns having the same total cost as the original solution. The existence of such alternative optimal solutions indicates other combinations of flow patterns that have the same cost on a system-wide basis. These alternative flow patterns are discussed where they occur.

6.2 The Cocoa Shipping Problem

Cocoa is grown mainly in the western states of Oyo, Ogun, and Ondo. Considerable quantities of cocoa are also grown in some other parts of the study area. The only internal demand point for cocoa is the Cocoa Industries Ikeja (C.I.A.), and by 1976/77 the industry was receiving its supply of cocoa from the former Western State Marketing Board. The remainder of the cocoa purchased by the Board is exported. The problem is to determine the optimal pattern of transporting cocoa from the supply points to Ikeja and the ports or the external destination in such a way that the cost incurred by the Board is minimized within the system.

6.2.1 Optimal Patterns of Cocoa Shipments to Ikeja and the Ports

The total shipping bill ($\sum \sum Xij\ Tij$) obtained from employing the road transport differential of the Cocoa Board (Cost 2) is higher than that obtained from Cost1 Model by 6.73 percent. This indicates that the Cocoa Board could have saved N15,896 on transportation of cocoa in 1976/77 if it had employed the sevices of the carriers instead of paying the licenced buying agents to transport the cocoa to the demand points. This would have enabled the Board to increase its net financial surplus.

The optimal pattern of shipments represents the minimum cost flows of the commodities between the supply regions and the demand points. Figures 32 and 33 indicate that the spatial patterns of these shipments are fairly similar. Generally, the demands for cocoa at Ikeja and at the ports are supplied from around the hinterland of each demand point.

All the optimal shipments in both models are not strictly made to the least cost ports for these supply regions nor did all supply regions ship to the same port in both models. For example, Ikole and Ado Ekiti which shipped to Sapele port in Cost1 Model, shipped to Lagos port in Cost2 Model although these shipments were being optimally made in both models. Also, Ubiaja, Agbor and Abudu which shipped to Sapele port in Cost1 Model were shipping to Port Harcourt port in Cost2 Model while Auchi which shipped to Sapele port in Cost1 Model was shipping to Port Harcourt port in Cost2 Model.

In Cost1 Model, the respective shipments to Port Harcourt port from Abudu, Agbor and Ubiaja cost N5.26, N4.56 and N4.80 more per tonne than shipments from these places to Sapele port. In Cost2 Model, in spite of the fact that shipments from Auchi to Port Harcourt employed the cheaper means of transportation by waterway on the River Niger, these shipments still cost more than shipments to Sapele port by N2.31 per tonne. These shipments to Port Harcourt port may have been made either to satisfy a strong demand for cocoa at Port Harcourt or may be due to insufficient demand for cocoa at Sapele port.

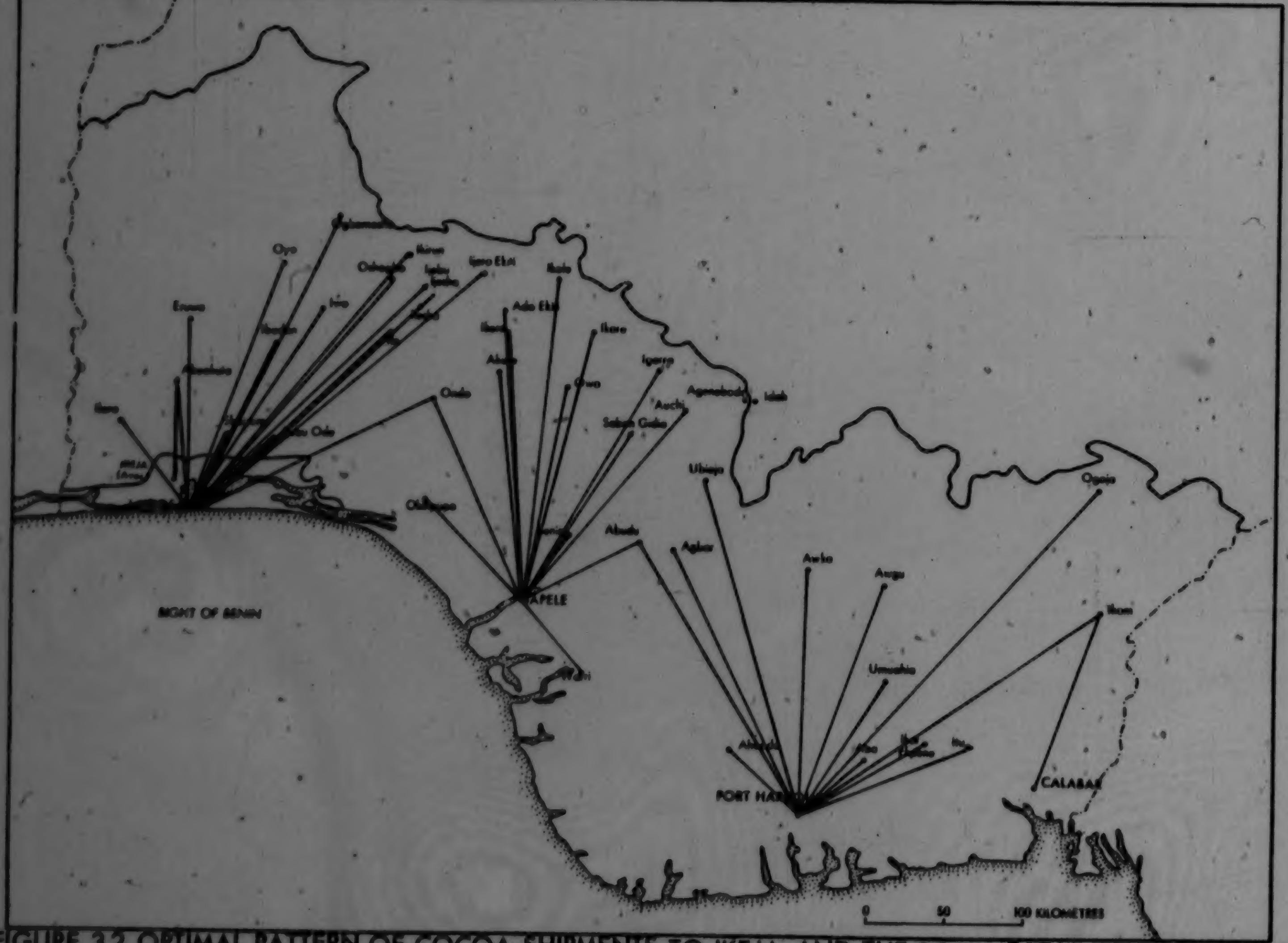

Oyo
Eruwa
Iwo
Ikirun
Iseyin
Ilaro
Ondo
Okitipupa
Ado Ekiti
Ikole
Ikare
Owo
Igarra
Auchi
Sabon Gida
Agenebode
Idah
Ubiaja
Abudu
Agbor
APELE
BIGHT OF BENIN
Awka
Awgu
Umuahia
Ogoja
Ikom
CALABAR
PORT HAR
0
50
100 KILOMETRES

FIGURE 32 OPTIMAL PATTERN OF COCOA SHIPMENTS TO IKEJA AND THE PORTS OBTAINED FROM COST 1.

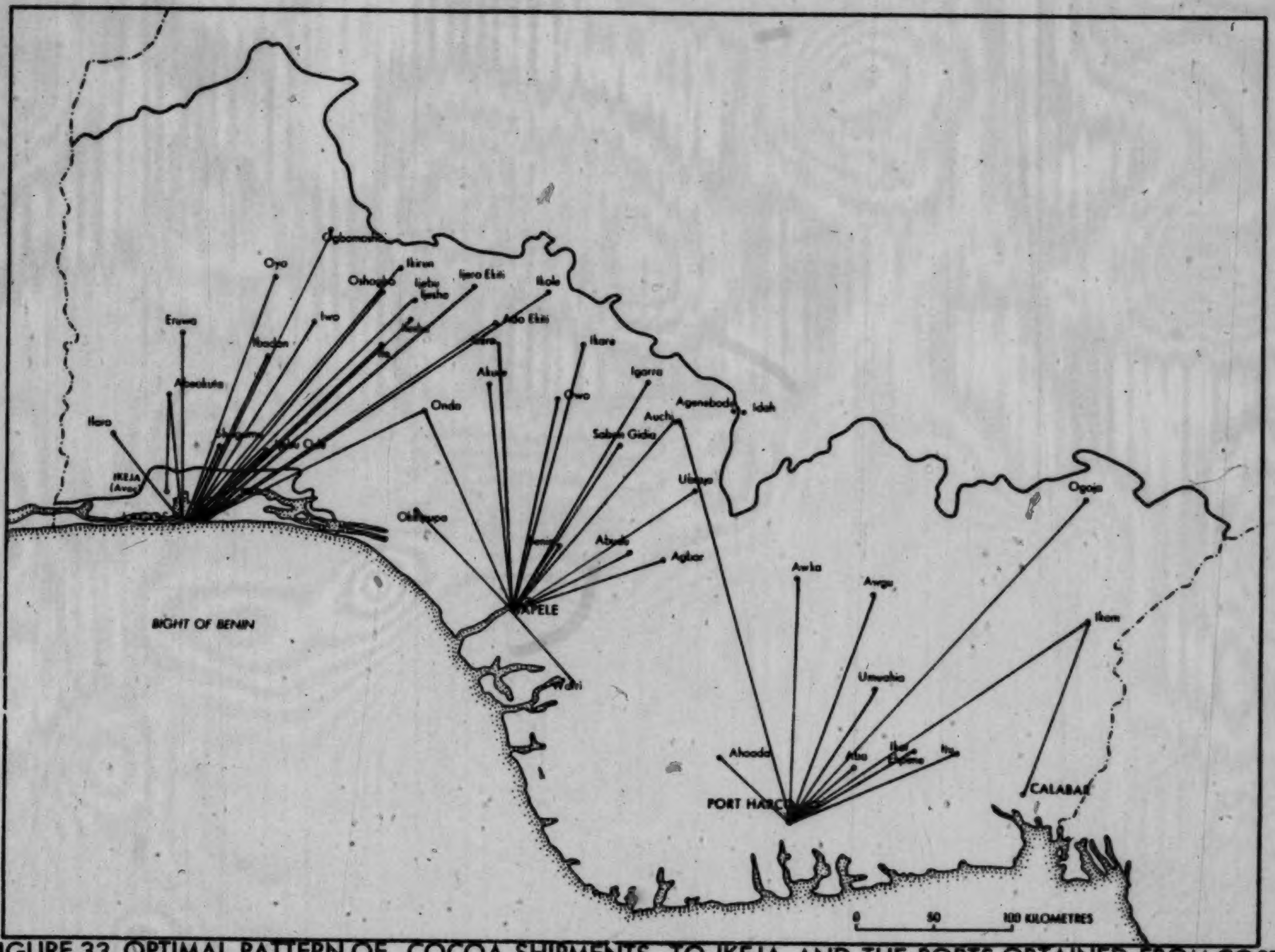

Oyo
Ikirun
Oshogbo
Ijebu Ijesha
Ijero Ekiti
Ikole
Iwo
Eruwa
Ibadan
Ado Ekiti
Ikare
Akure
Abeokuta
Igarra
Owo
Ondo
Agenebode
Idah
Auchi
Sabon Gidia
Ilaro
IKEJA (Area)
Okitipupa
Ubiaja
Abudu
Agbor
SAPELE
BIGHT OF BENIN
Warri
Awka
Awgu
Ogoja
Ikom
Umuahia
Ahoada
Aba
Ikot Ekpene
Itu
CALABAR
PORT HARC
0
50
100 KILOMETRES

FIGURE 33 OPTIMAL PATTERN OF COCOA SHIPMENTS TO IKEJA AND THE PORTS OBTAINED FROM COST 2

6.2.2 Optimal Dual Solution of Cocoa Shipments to Ikeja and the Ports

Whereas the physical interpretation of the primal is straightforward, the corresponding interpretation of the dual in empirical problems is not so evident. Problems arise with the meaning and exact interpretation of the dual objective function and inequalities in the dual constraints. The standard interpretation of the dual variables is that ui and vj represent the marginal values or the imputed prices of the commodity at the origin and demand points, respectively. This means that the ui's indicate the cost of shifting one unit of supply among the Si's or origins while the the vj's indicate the cost of shifting one unit of demand among the Dj's or destinations.

The U-V Algorithm employs the dual variables ui and vj to solve the Transportation Problem. In this method, it is required that a set of m+n-1 simultaneous equations in m+n unknowns be solved. In the solution process, it is evident that one equation (any one) is redundant because it can be obtained from others. Such a system of m+n-1 equations in m+n unknowns has an infinite number of solutions. Finding a particular solution requires that (m+n) - (m+n-1) = 1 variables be arbitrarily determined.

Since one constraint is redundant and must be arbitrarily determined, the conventional method discussed by Dantzig (1958), Gass (1969) and Hadely (1962) among others, is to set one of the dual variables at an arbitrary value in order to solve for the remaining dual variables. The equation usually employed in obtaining the remaining ui's and vj's is as follows:

$Cij - ui - vj = 0$, if Xij is basic.

This means that the dual variables are not uniquely determined, and the constraint, $ui, vj \geq 0$, is no longer respected, since these variables ui and vj are unrestricted as to sign.

Smillie (1972), in compiling the FORTRAN program LPTRNS, which was employed in this analysis, noted that (-ui) is the value of one unit of the commodity at the ith origin, and vj is the value of one unit of the commodity at the jth destination. The (-ui) measures the comparative locational value of the origins and the vj the comparative locational value of the destinations. He set the lowest ui equal to zero in order to solve for the remaining ui's and vj's, therefore the standard interpretation as marginal values is no longer possible. It is the differences between the implicit prices ui and vj, not the actual values of the dual variables that are important. These differences are relative cost factors and indicate how the supply or demand regions stand in relation to each other as supply or demand points.

Although the results obtained from the FORTRAN program LPTRNS indicate the relative differences between the supply and demand points, they are not very satisfactory and in some cases negative vj values which are difficult to interprete were obtained. In order to make the results easier to interprete, the highest ui value was subtracted from all the ui's and also added to all the vj's. The results obtained are more straightforward and indicate the relative differences in costs between the supply points (ui's) and between the demand points (vj's).

Thus, supply regions with high values of ui are more favourably located for producing cocoa than supply regions with lower values of ui. These are applicable if overall supplies or demands are to be increased or when investigating the savings in shipping bills which involve the entire system. Cocoa supply should therefore be increased in the areas with higher values of ui since it will result in greater savings in the shipping bill of the Cocoa Board to expand production in such places relative to other supply regions. Similarly, demand points with high values of vj are those demand points where increased demand for cocoa would result in less savings in the shipping bills incurred in the system. Such demand constraints are costly to the system and the demand for cocoa in such places should not be increased. On the other hand, increasing the demand at points with lower values of vj would result in greater savings in the shipping bills.

Figures 34 and 35 show the respective spatial patterns of the optimal dual solutions of the supply points (ui) for cocoa when Cost1 and Cost2 are employed in the model. These patterns generally indicate that the areas around the demand

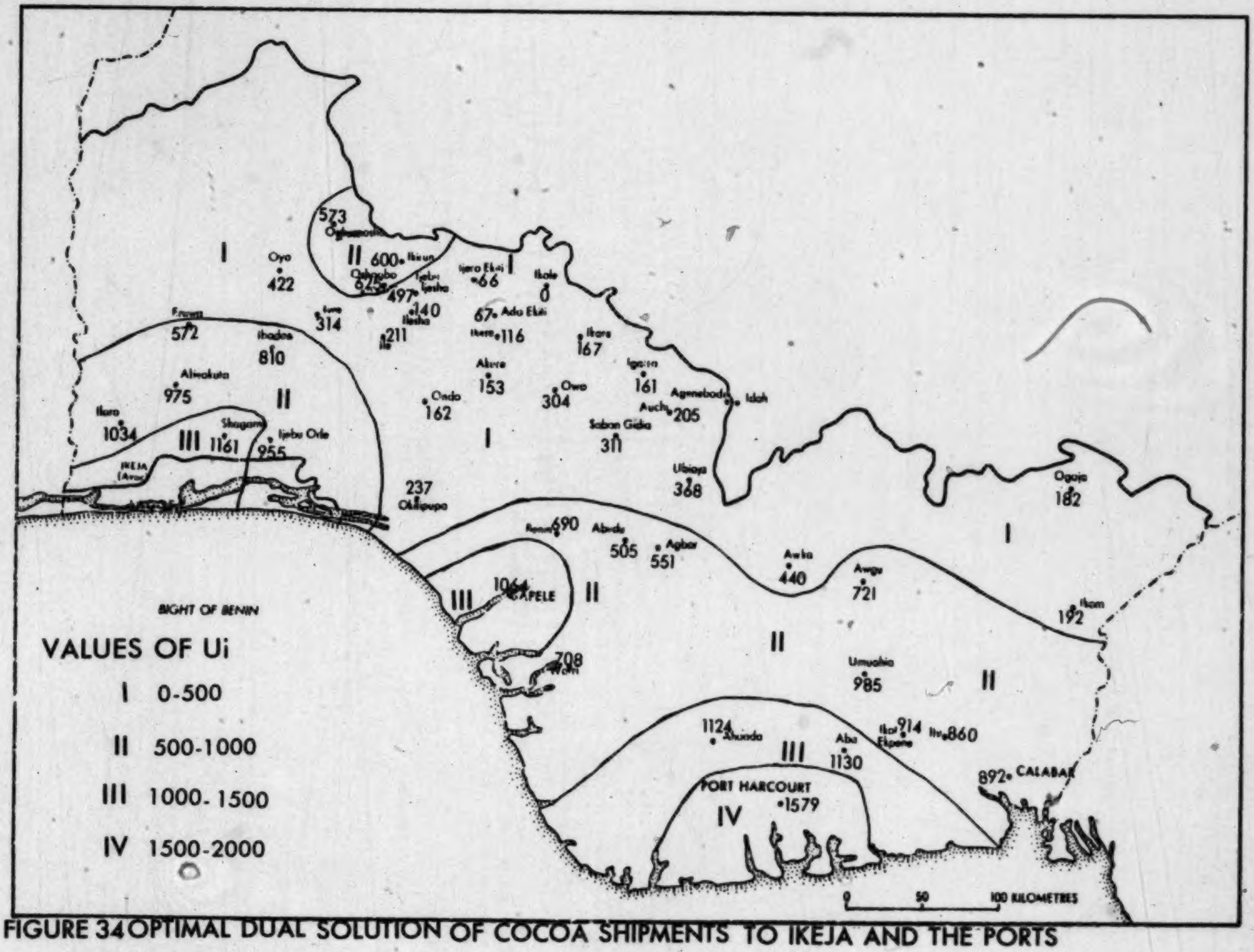

573
Ogbomosho
I
Oyo
422
II
600
Ikirun
Oshogbo
625
Ilesha
497
140
Ijero Ekiti
66
I
Ikole
0
Iwo
314
67
Ado Ekiti
Ikere
116
211
Ife
Ikare
167
Iseyin
572
Ibadan
810
Akure
153
Igarra
161
Abeokuta
975
II
Ondo
162
Owo
304
Agenebode
Idah
Auchi
205
Ilaro
1034
III
Shagamu
1161
Ijebu Ode
955
I
Sabon Gida
311
IKEJA (Apapa)
237
Okitipupa
Ubiaja
368
Ogoja
182
I
Benin
690
Abraka
505
Agbor
551
Awka
440
Awgu
721
III
1064
SAPELE
II
Ikom
192
BIGHT OF BENIN
II
708
Warri
Umuahia
985
II
1124
Ahoada
III
Aba
1130
Ikot Ekpene
914
Itu
860
892
CALABAR
PORT HARCOURT
1579
IV
0
50
100 KILOMETRES
VALUES OF Ui
I 0-500
II 500-1000
III 1000- 1500
IV 1500-2000

FIGURE 34 OPTIMAL DUAL SOLUTION OF COCOA SHIPMENTS TO IKEJA AND THE PORTS OBTAINED FROM COST 1.

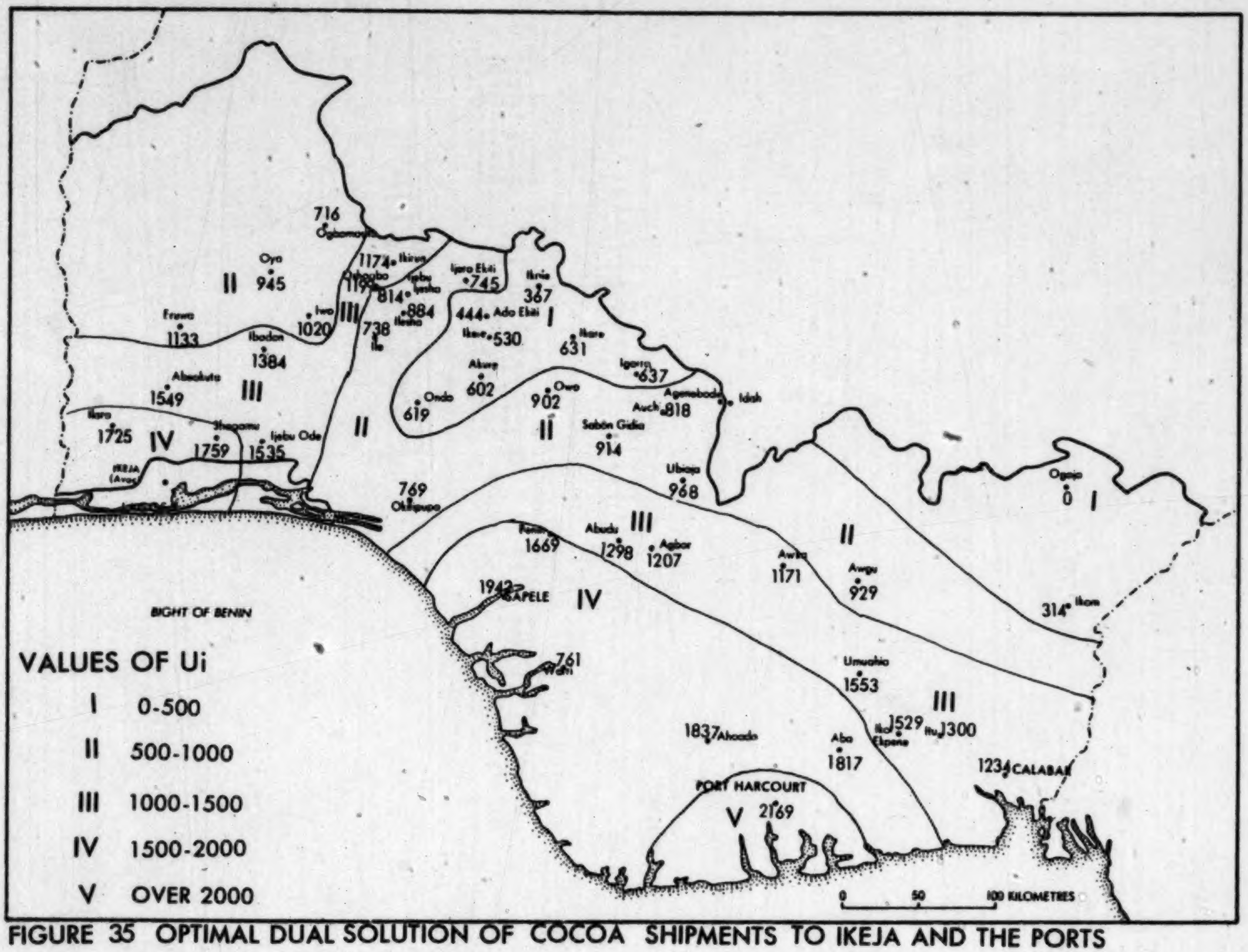

VALUES OF Ui
I 0-500
II 500-1000
III 1000-1500
IV 1500-2000
V OVER 2000
BIGHT OF BENIN
716 Ogbomosho
Oyo 945
Iwo 1020
Ibadan 1384
Abeokuta 1549
Ikoro 1725
Shagamu 1759
Ijebu Ode 1535
IKEJA (Awo)
1174 Ikirun
Oshogbo 1199
Ijebu Ijesha 814
884 Ilesha
738 Ile
Ijero Ekiti 745
Ikole 367
444 Ado Ekiti
Ikere 530
Ikare 631
Akure 602
Ondo 619
Owo 902
Igarra 637
Agenebode
Idah
Auchi 818
Sabon Gidia 914
Ubiaja 968
769 Okitipupa
Forcados 1669
Abudu 1298
Agbor 1207
1942 SAPELE
761 Warri
Awka 1171
Awgu 929
314 Ikom
Ogoja 0
Umuahia 1553
1837 Ahoada
Aba 1817
Ikot Ekpene 1529
Itu 1300
1234 CALABAR
PORT HARCOURT 2169
I
II
III
IV
V
0 50 100 KILOMETRES

FIGURE 35 OPTIMAL DUAL SOLUTION OF COCOA SHIPMENTS TO IKEJA AND THE PORTS OBTAINED FROM COST 2

points or ports are the areas best located for cocoa production if shipping cost were the only factor to be taken into consideration. The values of ui are higher around these ports and decrease northwards to the areas in the interior which are least favourable for cocoa production because they involve higher shipping bills. In both models, Port Harcourt with the highest ui value of 1597 in Cost1 Model and 2169 in Cost2 Model is the supply point that is most favourably located for cocoa production. This is undoubtedly related to the function of Port Harcourt as a demand point for cocoa because its demand constraint is the most costly to the system.

Table 16 illustrates the relative costs of changing the demand capacity for cocoa at all the demand points. In both models, the comparative locational values of the demand points are similar since these destinations stand in the same order with regard to increasing the demand capacity of cocoa in these models. Port Harcourt port (vj = 1674 in Cost1 Model and vj =2264 in Cost2 Model) is the most expensive location for increasing the demand capacity for cocoa. Calabar port with vj value of 984 in Cost1 Model and vj value of 1325 in Cost2 Model is the least expensive demand point for increasing the demand for cocoa. Other demand points fall in between these two extremes in the same order.

In Cost1 Model, to increase the demand capacity for cocoa at Calabar port will reduce cost by 690 (1674 - 984 =

TABLE 16. THE DEMAND DUAL SOLUTION (VJ) OF THE COCOA SHIPPING PROBLEM TO IKEJA AND THE PORTS

NAME OF DEMAND POINT	Vj IN COST1	Vj IN COST2
PORT HARCOURT	1674	2264
LAGOS	1661	2251
IKEJA (C.I.A)	1631	2205
SAPELE	1155	2033
CALABAR	984	1325

690) more than at Port Harcourt port. Therefore, the Cocoa Board will incur higher shipping bill if demand for cocoa were expanded at Port Harcourt port than if demand were increased at Calabar port. Similarly, increasing the demand capacity for cocoa at Lagos and Port Harcourt ports will increase the shipping bills incurred by the Cocoa Board than if demand were increased at Sapele and Calabar ports. To increase demand for cocoa at Ikeja, the only internal demand point for cocoa is more expensive to the system (647) than increasing demand at Calabar port. It is also more costly to increase demand at Ikeja(476) than to increase demand at Sapele port. Similar relationships were also obtained from the optimal dual solution of the demand points (vj) from Cost2 Model.

On the whole, Port Harcourt is the least favourable demand point for increasing cocoa demand under the system of cocoa supplies and demands of 1976/77. This explains why it was also the most favourable supply region for expanding cocoa supply. This is expected because the shipping bills of the Cocoa Board would naturally be reduced if the supply of cocoa were increased in the demand point where it is most expensive to increase demand.

The results obtained from the optimal solution and the dual solution to the cocoa shipping problem in Nigeria indicate that apparently suboptimal shipments which are more expensive to the system were being made because of the nature of the demand for cocoa at the respective demand points. The relative costs of shifting demand capacity at these demand points suggest that there may be advantages in shifting the actual demands at the ports. The results of the models suggest that the Cocoa Board could have saved more on shipping bills if the demand capacity for cocoa at Sapele and Calabar were increased whereas expanding the demand for cocoa at Port Harcourt and Lagos ports would have increased the shipping bills incurred by the Board in 1976/77. Since the cocoa demanded at the ports is for export, it is not necessary that these port demands which are expensive to the Board be strictly adhered to. These demands could be adjusted by allowing the supply points to ship directly to the export market. These relationships and results are further investigated when the demand at one destination, or the outside world is considered.

6.2.3 Linkage Allocation and Modal Composition of Cocoa Shipments to Ikeja and the Ports

Apart from shipping optimally to the ports and the demand points, inefficiencies in the cocoa shipping pattern in Nigeria may arise from inefficient utilization of various modes of transportation. This may be caused by improper selection of the most economical modes of transport for given regional patterns of supply and demand for this commodity. The costs of transhipment have been provided at the transhipment centres which would allow inter-modal transfers to be made. Figures 36 and 37 show the respective linkage allocations on various modes of transportation obtained from Cost1 and Cost2 Models. Generally, long-hauls were preferred to the hauls on the direct links because they are less expensive than total sum of the short hauls. The demand for cocoa at the cocoa industry Ikeja (C.I.A) was supplied from Abeokuta on both models. This shipment was made by rail because it is cheaper than shipping by road on other available routes.

In Cost1 Model, only the cocoa producing areas located on the Western Railway District shipped to Lagos port by rail while Aba and Umuahia on the Eastern Railway District shipped to Port Harcourt port by road. This may indicate that the road freight rates of the carriers are often less expensive than rail freight rates for short distances. This may be attributed to the fact that the freight rates for short hauls by rail are influenced by the high terminal costs for this mode. Apart from the cocoa shipments on the railway already mentioned, and the cocoa shipment from Awka which transhipped to the River Niger at Onitsha, all the other shipments in this model were made by road, and all by

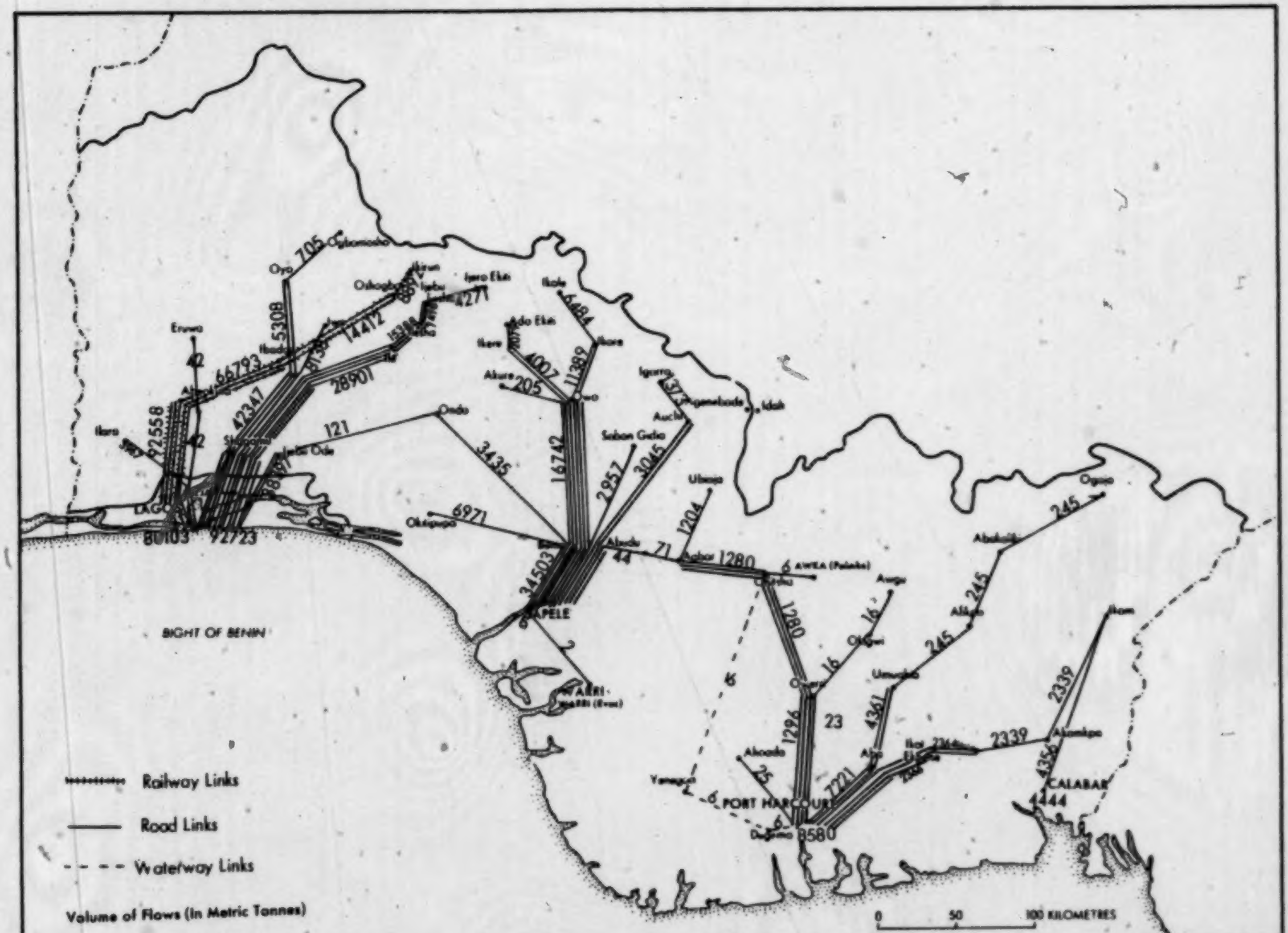

Oyo
705
Ogbomosho
5308
Oshogbo
Ikirun
Ilesha
Igero Ekiti
4271
14412
Ibadan
66793
28901
Erunwa
42
Ilaro
92558
42347
Ijebu Ode
121
Ondo
3435
LAGOS
80103
92723
Okitipupa
6971
Ado Ekiti
Ikere
4007
Akure
205
Ikole
6484
Ikare
11389
Owo
16742
Igarra
1373
Agenebode
Idah
Auchi
Sabon Gida
2957
3045
Ubiaja
1204
Abudu
71
44
Agbor
1280
6
AWKA (Paleeke)
SAPELE
34503
2
WARRI
WARRI (Ewu)
BIGHT OF BENIN
Onitsha
1280
Awgu
16
Okigwi
16
Owerri
1296
23
6
Yenagoa
Ahoada
25
PORT HARCOURT
6
Degema
8580
Umuahia
4361
Aba
7221
Ikot Ekpene
2339
Afikpo
245
Abakaliki
245
Ogoja
Ikom
2339
Akamkpa
4356
CALABAR
4444
Railway Links
Road Links
Waterway Links
Volume of Flows (In Metric Tonnes)
0
50
100 KILOMETRES

FIGURE 36 MODAL COMPOSITION AND LINKAGE ALLOCATIONS OF COCOA SHIPMENTS TO IKEJA AND THE PORTS OBTAINED FROM COST 1.

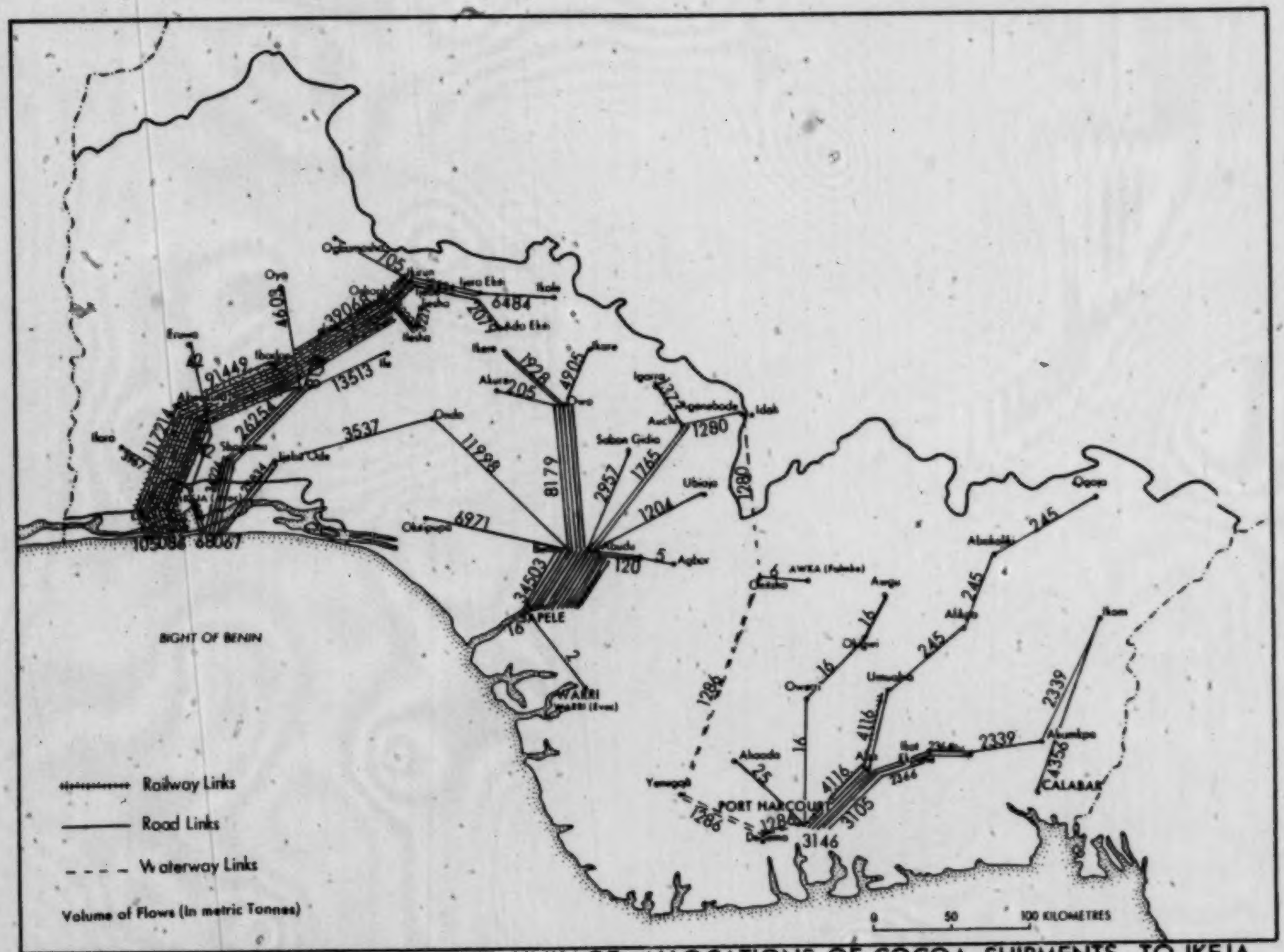

Oyo
4603
Erumo
42
91449
Ibadan
39068
705
Ogbomosho
Iwo
Osogbo
Ilesha
Ijero Ekiti
Ikole
6484
2074
Ado Ekiti
13513
117214
Ilaro
3987
26254
Shagamu
Ijebu Ode
3537
IKEJA
105088
68067
Ondo
11998
Ikare
Ikere
1928
4905
Akure
205
Owo
8179
Okitipupa
6971
Saban Gida
2957
1765
Igarra
1272
Agenebode
Auchi
1280
Idah
1280
Ubiaja
1204
Abudu
5
Agbor
120
34503
SAPELE
16
2
WARRI
WARRI (Escravos)
BIGHT OF BENIN
6
AWKA (Palm)
Onitsha
1286
Awgu
16
Okigwi
16
Owerri
16
Abakaliki
245
245
Afikpo
245
Umuahia
4116
Aba
4116
Ikot Ekpene
2339
2346
3105
Ikom
2339
Akamkpa
4356
CALABAR
Ahoada
25
Yenagoa
1286
PORT HARCOURT
1286
Degema
3146
Railway Links
Road Links
Waterway Links
Volume of Flows (In metric Tonnes)
0
50
100 KILOMETRES

FIGURE 37 MODAL COMPOSITION AND LINKAGE ALLOCATIONS OF COCOA SHIPMENTS TO IKEJA AND THE PORTS OBTAINED FROM COST 2

long-hauls. Thus, this model seems to be emphasizing that most of the cocoa shipments to the demand points should be made by road using the road freight rates of the carriers.

A different pattern of modal utilization was obtained from Cost2 Model (Figure 37). In this model, all cocoa producing regions along both the Western and Eastern Railway Districts transported cocoa by rail to either Lagos or Port Harcourt ports. In addition to these, six other producing regions in the west (Ogbomosho, Ijero Ekiti, Ikole, Ado Ekiti, Ijebu Ijesha, and Ilesha) started-off by road but transhipped to the railway at either Ikirun or Oshogbo and from these points to Lagos port. These shipments were all long-hauls from Ikirun and Oshogbo. Awka and Auchi also started-off by road but transhipped to less expensive waterway transportation at Agenebode and Onitsha, respectively and from these places to Port Harcourt port.

Cost2 Model involved more transhipments between the modes than Cost1 Model. Cost1 Model suggested that only 40.6 percent of the total cocoa exported through Lagos port be shipped by rail while Cost2 Model suggested that as much as 60.8 percent of cocoa exported through Lagos port be shipped by rail. Similarly, Cost1 Model did not suggest that any shipments of cocoa through Port Harcourt be made by rail. On the other hand, Cost2 Models suggested that the cocoa from Umuahia, which constitutes 48 percent of total shipments through Port Harcourt port, be made by rail and 15 percent be made by waterway.

Thus, it would seem that although the road transport differential set by the Boards encourages the use of the railway more that the rates set by the carriers, it is possible for the licensed buying agents to avoid shipping by rail if they obtain the cheaper negotiated rates of the carriers. In fact, the Cocoa Board could have been shipping more efficiently either by employing the carriers instead of the buying agents or by employing the services of the agents and transhipping to cheaper rail or waterway modes. These findings are contrary to the present system of marketing and transporting export commodities in Nigeria. The Commodity Boards continue to employ the services of the licenced buying agents in spite of the higher shipping bills they incur. These higher bills cannot be justified unless there are other non-economic functions which the agents perform for the Commodity Boards.

6.2.4 Formulating the Model to Ship to One External Destination

The major objective of the Commodity Boards is not only to get the commodities to the ports but to actually get them to the foreign markets or the outside world. The results of the models indicate that the nature of the demands for cocoa at the ports lead to apparent sub-optimal shipping patterns involving higher shipping bills. Therefore, further investigation was carried out in this direction. The ports demand these commodities, not for their own consumption but in order to ship them to foreign markets. It was, therefore, considered appropriate to compare the results of the models obtained from the given port demands with the pattern of demand that would minimize total shipping bills from the supply points directly to the foreign market.

The same problem was reformulated in a different way in order to investigate whether the pattern of port demands could be adjusted to enable a more efficient internal shipping pattern and still satisfy the demand by the foreign markets. This may reveal whether the given export demand schedules are inadequate with respect to internal shipping bills incurred by the Commodity Boards.

All the foreign markets were lumped together as one major destination. The study is concerned with the pattern of transportation within Nigeria and not with how the commodities are transported to the respective European and North American markets. It is also assumed that once these commodities leave the Nigerian ports they will be eventually sold in these foreign markets in order to obtain foreign exchange. It was, therefore, a logical pragmatic approach to consider all the demands formerly made at the various seaports to be made at this one major destination or foreign market. This formulation will enable the effect of alternative port demand and port policies on internal shipping bills to be determined.

Since the demands formerly made at the ports were now assumed to be made at one major external destination the ports now have zero demand and were treated as transhipment points. They were connected to this major destination by links of equal transportation cost. A nominal cost of N1.00 was employed, and this was subtracted from the total shipping bill for each solution obtained in this formulation in order to make them comparable with the earlier models.

These adjustments made it possible for the origins to ship to any port and presumably this should be the least cost port because the external demand can be satisfied through any of the ports. Thus, this reformulation of the model emphasizes the important assumption that the Commodity Boards are free to ship export commodities through any of the ports in order to minimize shipping costs and increase their net financial surplus.

6.2.5 Optimal Pattern of Cocoa Shipments to Ikeja and One Major Destination

The total shipping bill ($\sum \sum Xij\ Tij$) obtained from all the models in this reformulation were lower than their corresponding models in the earlier formulation. The lower total costs of these models indicate that a more rationalized demand for cocoa at the ports would considerably reduce the inland shipping bills incurred by the Commodity Board for transporting cocoa in Nigeria. The total shipping bills in Cost1 Model to one major destination is 93 percent of the earlier model while in Cost2 Model to one major destination, the total shipping bill is 98 percent of the earlier model. Thus, this reformulation result in greater savings in shipping bill for Cost1 Model (N158,699) than for Cost2 Model (N46,707). This indicates that in terms of the road transport differential rate of the Board the existing demand system at the ports was only 1.9 percent inefficient while the same system was 7 percent inefficient in terms of the road transport freight rates of the carriers. This suggests that although the rates set by the Board were originally higher than the rates set by the transport firms, the Board rates were also more oriented to satisfying the existing port demand for cocoa than to satisfying the demand for Nigerian cocoa in the external destination or foreign market.

The total cost of the model obtained from employing the road transport differential of the Commodity Boards (Cost2 Model) is 12.6 percent higher than the total cost of the model obtained from the road freight rate of the carriers (Cost1 Model). This indicates that if it is assumed that the Cocoa Board were already employing the road transport freight rates of the transport firms, it would have saved an additional 5.78 percent of this former total shipping bill in 1976/77, by adjusting the demand schedules for cocoa at the ports as well.

Figures 38 and 39 indicate the respective spatial patterns of the optimal shipments through the ports to one major destination when Cost1 and Cost2 are employed. In both models, the inefficient long-haul shipments from Ikom and

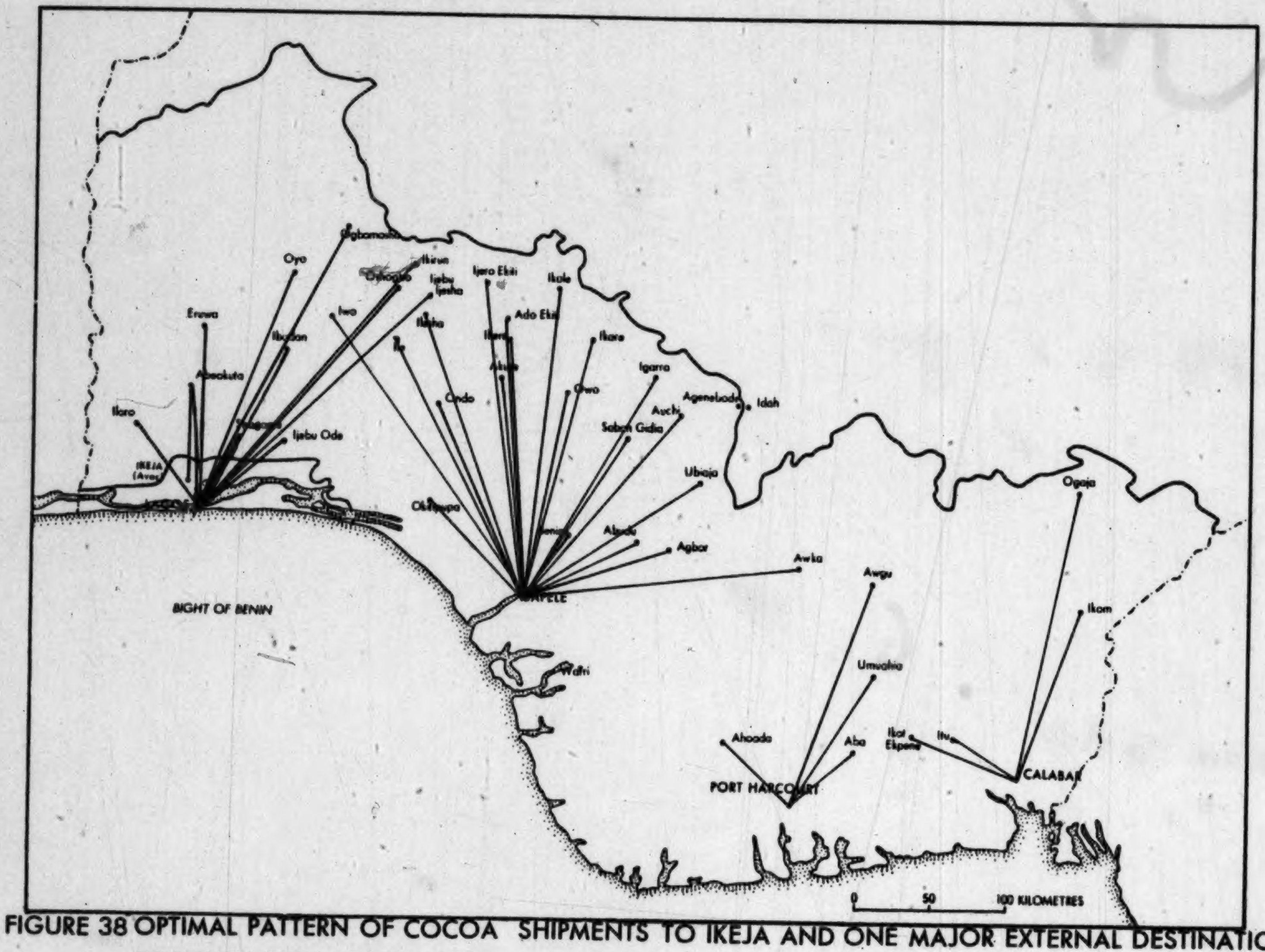

Ogbomosho
Oyo
Ikirun
Oshogbo
Ijebu Ijesha
Ijero Ekiti
Ikole
Erewa
Iwo
Ilesha
Ado Ekiti
Ibadan
Ife
Ikare
Abeokuta
Akure
Igarra
Ondo
Owo
Agenebode
Idah
Ilaro
Auchi
Saban Gidia
Ijebu Ode
IKEJA (Avas)
Ubiaja
Okitipupa
Abraka
Agbor
Awka
SAPELE
Awgu
Ogoja
BIGHT OF BENIN
Ikom
Warri
Umuahia
Ahoada
Aba
Ikot Ekpene
Itu
CALABAR
PORT HARCOURT
0
50
100 KILOMETRES

FIGURE 38 OPTIMAL PATTERN OF COCOA SHIPMENTS TO IKEJA AND ONE MAJOR EXTERNAL DESTINATION OBTAINED FROM COST 1

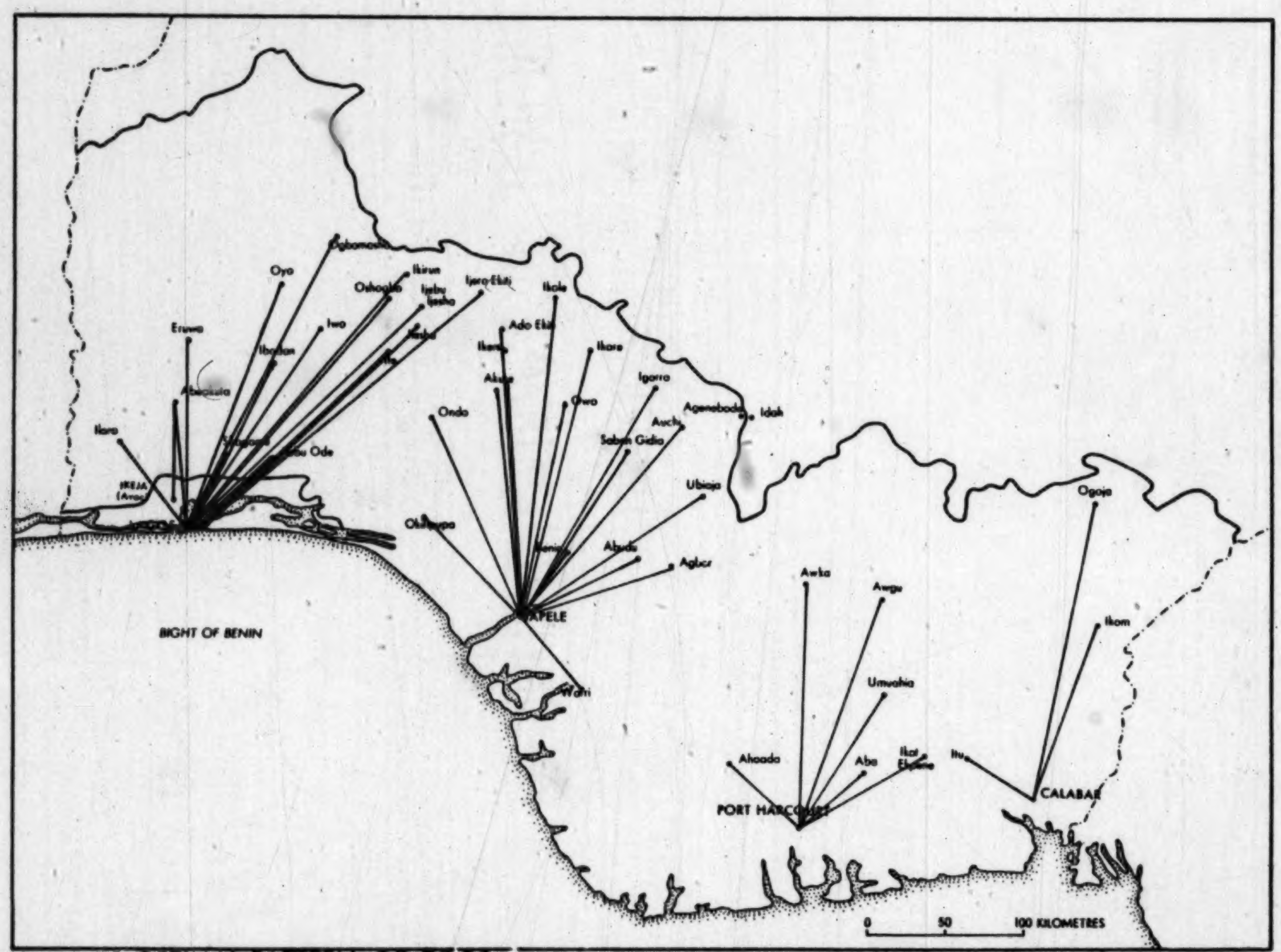

Ogbomosho
Oyo
Iwo
Eruwa
Ibadan
Abeokuta
Ilaro
IKEJA (Area)
Shagamu
Ijebu Ode
Oshogbo
Ikirun
Ijebu Ijesha
Ilesha
Ife
Ijero Ekiti
Ado Ekiti
Ikere
Akure
Ondo
Okitipupa
Ikole
Ikare
Owo
Igarra
Auchi
Sabon Gida
Agenebode
Idah
Ubiaja
Abudu
Agbor
Benin
SAPELE
Warri
BIGHT OF BENIN
Awka
Awgu
Umuahia
Ahoada
Aba
Ikot Ekpene
Itu
PORT HARCOURT
CALABAR
Ikom
Ogoja
0
50
100 KILOMETRES

FIGURE 39 OPTIMAL PATTERN OF COCOA SHIPMENTS TO IKEJA AND ONE MAJOR EXTERNAL DESTINATION OBTAINED FROM COST 2

Ogoja to Port Harcourt were eliminated and both supply points now shipped optimally through Calabar port. The unnecessarily expensive long-haul shipments from Ubiaja, Agbor and Abudu to Port Harcourt port in the former Cost1 Model and from Auchi to Port Harcourt in the former Cost2 Model were eliminated and these ports shipped through their least cost port of Sapele. The shipment from Iwo to Sapele in Cost1 Model is an apparent anomaly. It may have been possible that shippers sampled wrongly underestimated the cost from Iwo to Sapele port or overestimated the cost from Iwo to Lagos port.

There are a few minor differences in the patterns obtained from the two models. While Ikot Ekpene shipped through Calabar port to one major destination in Cost1 Model, it shipped through Port Harcourt port in Cost2 Model. The spatial pattern of shipments obtained from Cost2 Model indicates the tendency for supply regions shipping through the ports to the external destination to be more concentrated in definite hinterlands above these ports than the pattern obtained from Cost1 Model. Thus, while the hinterland for Sapele port includes such places as Iwo, Ife, Ilesha, Ijero Ekiti and Awka in Cost2 Model (Figure 38) it did not extend to these places in Cost1 Model (Figure 39). This may be attributed to the fact that the long-hauls give a greater advantage in shipping costs when the road transport freight rates of the carriers (Cost1) are employed.

6.2.6 The Spatial Pattern of the Optimal Dual Solution of Cocoa Shipments to Ikeja and One Major Destination

The respective spatial pattern of the optimal dual solution of the origins (ui) obtained for the cocoa shipping problem to one major destination when Cost1 and Cost2 are employed in the model are illustrated in Figures 40 and 41. As in the earlier models, these patterns indicate that the greatest savings in shipping bills will be incurred if cocoa were produced in the immediate hinterland of these ports. In both models, Calabar, Port Harcourt and Sapele ports have the highest relative ui values of 1259, 1255, and 1259 in Cost1 Model and 1641, 1637 and 1641 in Cost2 Model, respectively instead of Port Harcourt port that had this highest relative value in the earlier models. Therefore, these places are best located for producing cocoa if shipping bills were the only factor to be taken into consideration. The relative shipping cost decrease from these ports towards the interior which are less favourably located for increasing cocoa supply. The decline is more gradual in Cost1 Model than in Cost2 Model.

The relative value of the dual variables of the demand points suggest that it would cost more to increase demand capacity at the external destination (1450) than to increase demand at Ikeja (1320) in Cost1 Model. Similar results were also obtained from Cost2 Model in which the external destination had a vj value of (1832) while Ikeja had a value of (1702). Thus, more processing of cocoa within the country

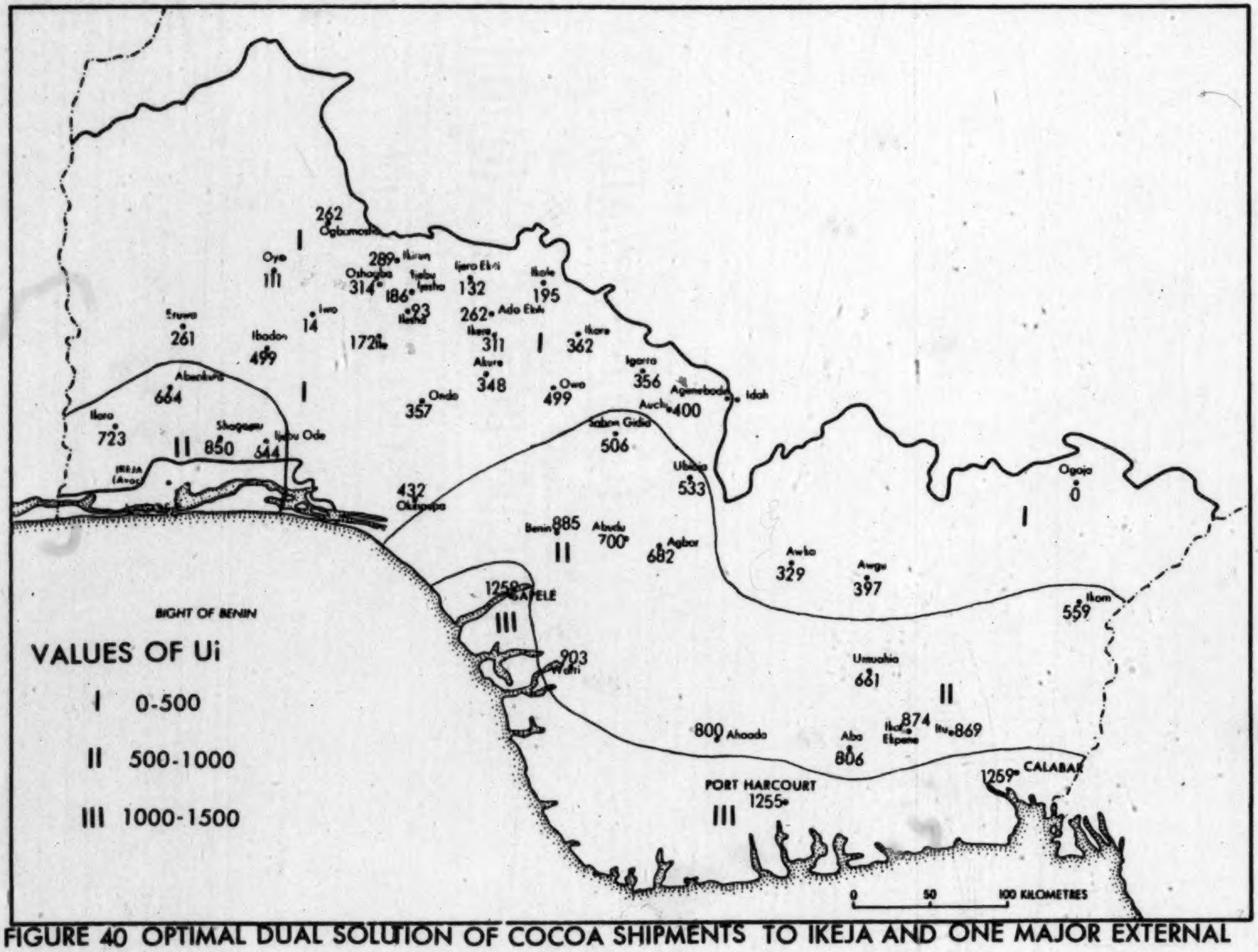

VALUES OF Ui
I 0-500
II 500-1000
III 1000-1500
BIGHT OF BENIN
262 Ogbomosho
Oyo 111
289 Ikirun
Oshogbo 314
Ijebu Ijesha 186
93 Ilesha
Ijero Ekiti 132
Ikole 195
262 Ado Ekiti
Iwo 14
Eruwa 261
Ibadan 499
172 Ife
Ikere 311
Ikare 362
Akure 348
Owo 499
Ondo 357
Igarra 356
Agenebode
Idah
Auchi 400
Sabon Gidda 506
Abeokuta 664
Ilaro 723
Shagamu 850
Ijebu Ode 644
IKEJA (Agege)
432 Okitipupa
Ubiaja 533
Benin 885
Abudu 700
Agbor 682
Awka 329
Awgu 397
Ogoja 0
Ikom 559
1259 SAPELE
903 Warri
Umuahia 681
800 Ahoada
Aba 806
Ikot Ekpene 874
Itu 869
PORT HARCOURT 1255
1259 CALABAR
I
II
III
0 50 100 KILOMETRES

FIGURE 40 OPTIMAL DUAL SOLUTION OF COCOA SHIPMENTS TO IKEJA AND ONE MAJOR EXTERNAL DESTINATION OBTAINED FROM COST 1.

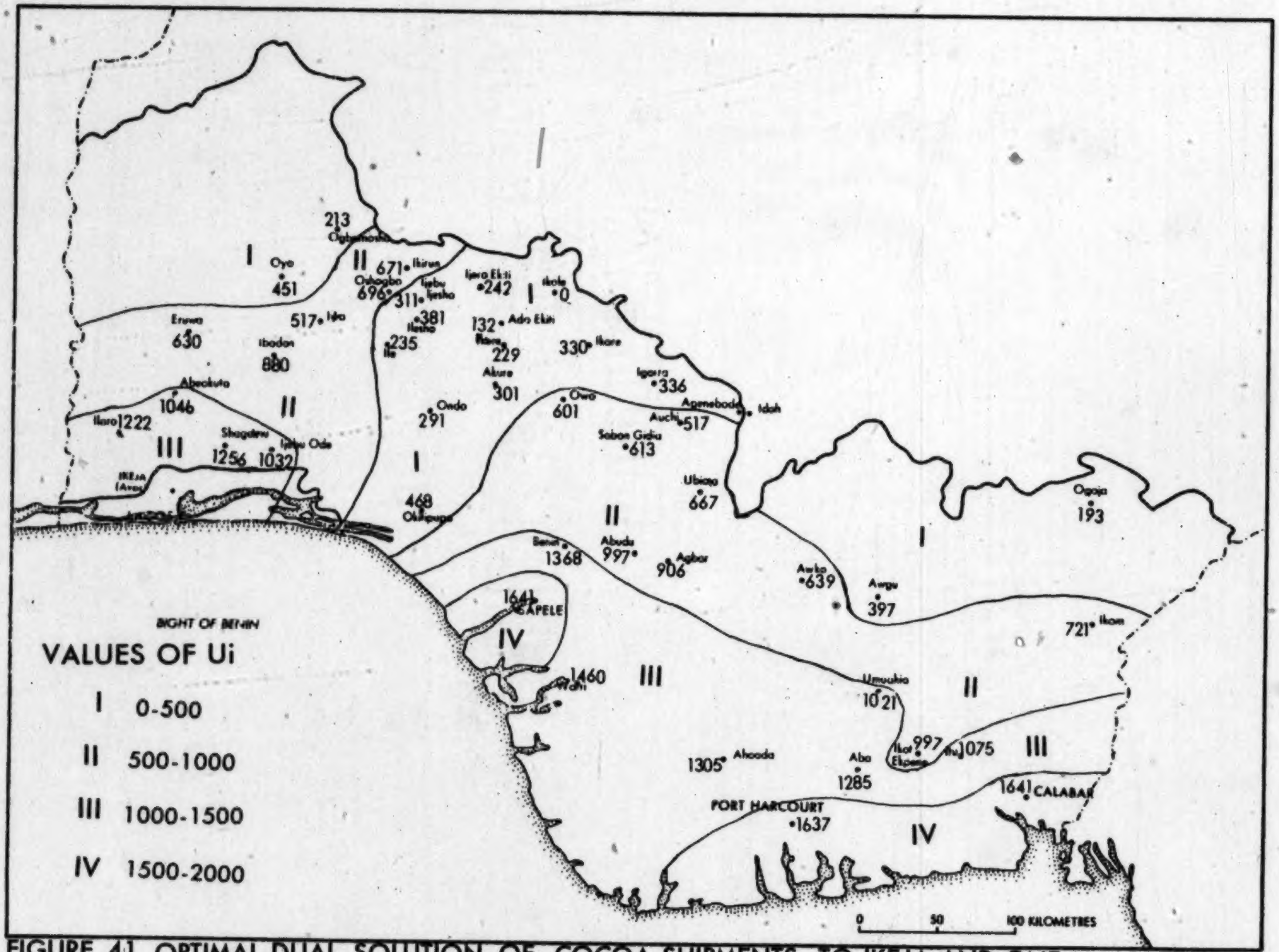

I
II
III
IV
213
Ogbomosho
Oyo
451
671 Ikirun
Oshogbo
696
Ijebu Ijesha
311
381
Ilesha
235
Ile
Ijero Ekiti
242
Ikole
0
132 Ado Ekiti
Ifara
229
330 Ikare
Akure
301
Igarra
336
Eruwa
630
517 Iwo
Ibadan
880
Abeokuta
1046
Ilaro 1222
Shagamu
1256
Ijebu Ode
1032
IKEJA (Area)
Ondo
291
Owo
601
Agenebode
Idah
Auchi
517
Sabon Gidiu
613
468
Okitipupa
Ubiaja
667
Benin
1368
Abudu
997
Agbor
906
Awka
639
Awgu
397
Ogoja
193
721 Ikom
1641
SAPELE
1460
Warri
Umuahia
1021
Ikot Ekpene
997
Itu 1075
Ahoada
1305
Aba
1285
1641 CALABAR
PORT HARCOURT
1637
BIGHT OF BENIN
VALUES OF Ui
I 0-500
II 500-1000
III 1000-1500
IV 1500-2000
0
50
100 KILOMETRES

FIGURE 41 OPTIMAL DUAL SOLUTION OF COCOA SHIPMENTS TO IKEJA AND ONE MAJOR EXTERNAL DESTINATION OBTAINED FROM COST 2

will reduce the shipping bill of the Cocoa Board.

6.2.7 Linkage Allocations and Modal Composition of Cocoa Shipments to Ikeja and One Major Destination

Generally, the models performed in the same way as their respective equivalents. Cost1 Model still makes more shipments by road than Cost2 Model. As in the former model, only the cocoa producing areas along the Western Railway District shipped cocoa by rail in Cost1 Model (Figure 42). Similarly, Cost2 Model still indicates the preferences for transhipments to the railway. As in the former model, all cocoa producing regions on the Eastern and Western Railway Districts shipped by rail. In addition to these, four other supply points in the west (Ijebu Ijesha, Ilesha, Ijero Ekiti and Ogbomosho) transhipped to the rail at either Ikirun or Oshogbo in order to ship through Lagos port to the external destination. This model suggests that 60.2 percent of the total shipments of cocoa passing through Lagos port to the external destination be made by rail. Awka still ships to Onitsha where it tranships to the less expensive route by waterway on the River Niger in order to ship through Port Harcourt port to the external destination (Figure 43).

The preference for transhipment to the cheaper modes in Cost2 Model may be reflecting the adverse effects of the expensive road transport differential of the Commodity Boards. These rates seem to be so high that many shipments that started-off by road are still less expensive after

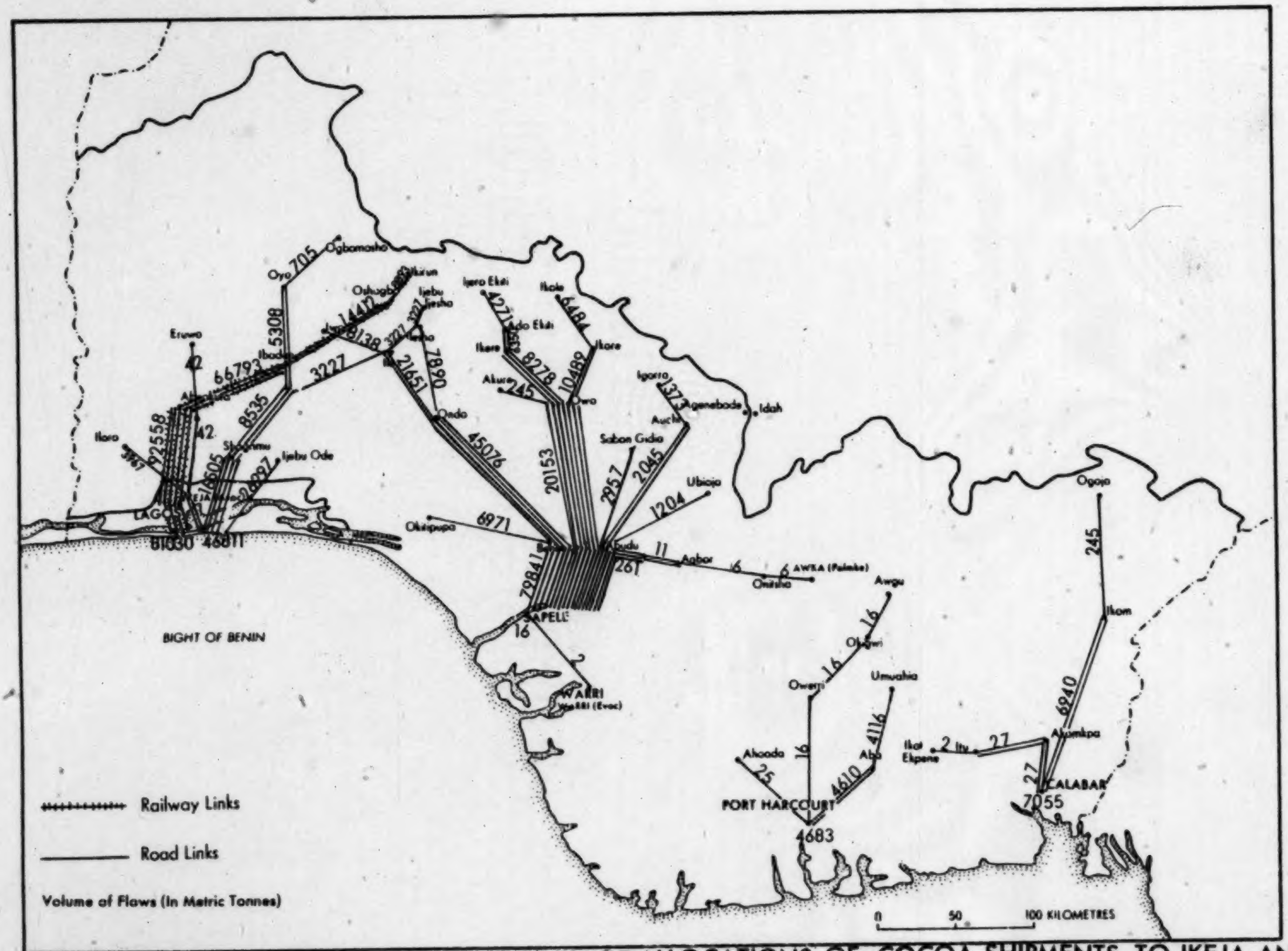

Oyo
705
Ogbomosho
5308
Ikirun
Oshogbo
14412
Ibadan
66793
8138
3221
Ijebu Jesha
Ilesha
3227
Eruwa
42
Abeokuta
92558
42
Ilaro
8535
Shagamu
16505
Ijebu Ode
26897
IKEJA
LAGOS
81030
46811
21651
7890
Ondo
45076
Igero Ekiti
4271
Ado Ekiti
Ikere
8278
Ikole
6484
Ikare
10489
Owo
Akure
245
20153
Okitipupa
6971
Benin
79841
SAPELE
16
WARRI
Warri (Evac)
2
Saban Gidia
2957
Igarra
1373
Agenebode
Idah
Auchi
2045
Ubiaja
1204
Uwudu
11
261
Agbor
6
Onitsha
6
AWKA (Palmke)
Awgu
16
Okigwi
16
Owerri
Umuahia
16
Ahoada
25
Aba
4116
4610
PORT HARCOURT
4683
Ikot Ekpene
2
Itu
27
Akamkpa
27
CALABAR
7055
6940
Ikom
245
Ogoja
BIGHT OF BENIN
Railway Links
Road Links
Volume of Flows (In Metric Tonnes)
0
50
100 KILOMETRES

FIGURE 42 MODAL COMPOSITION AND LINKAGE ALLOCATIONS OF COCOA SHIPMENTS TO IKEJA AND ONE MAJOR EXTERNAL DESTINATION OBTAINED FROM COST 1.

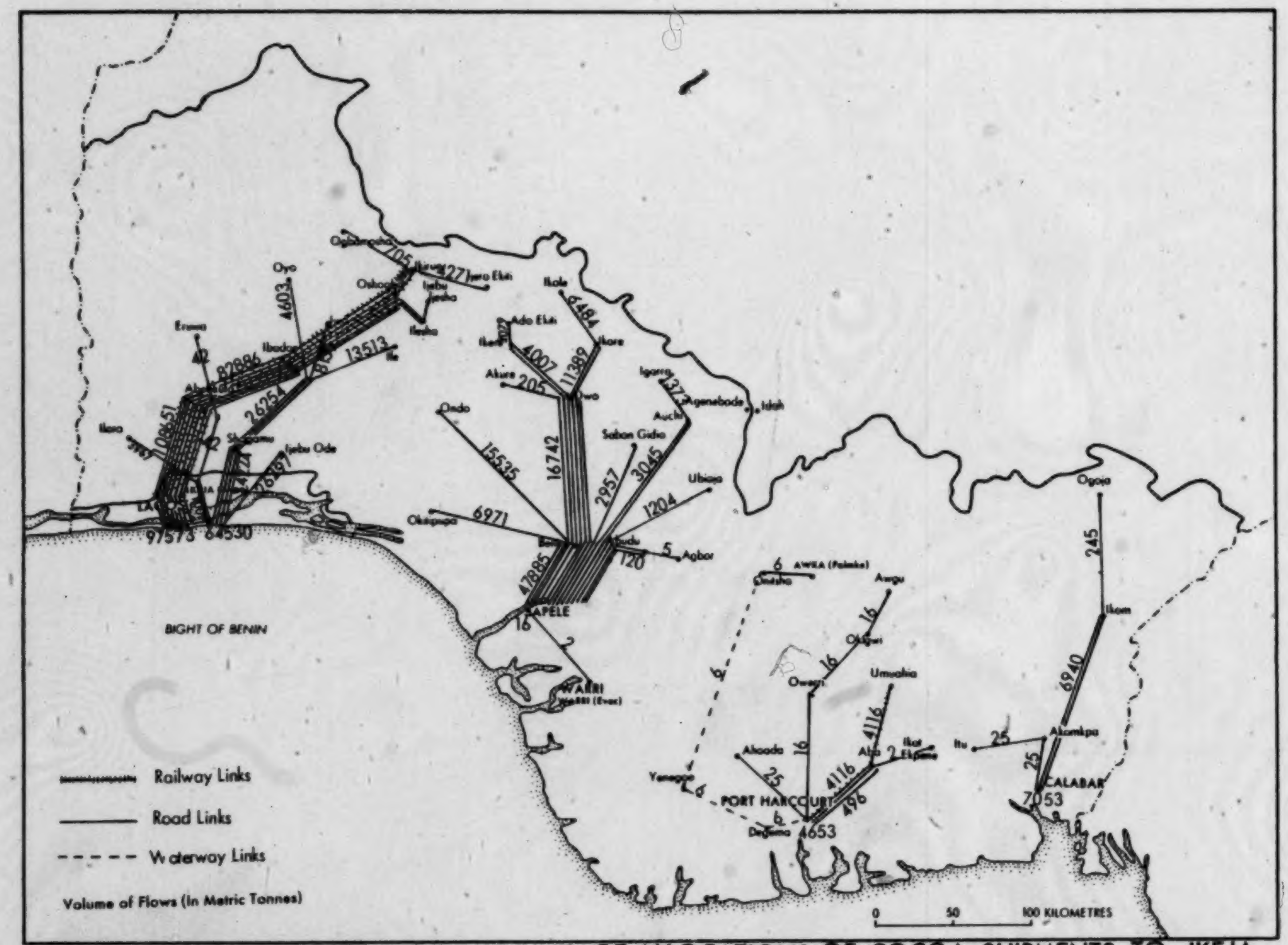

Oyo
4603
Ogbomosho
705
Ikirun
327
Iyero Ekiti
Oshogbo
Ijebu
Ijesha
Ilesha
Erunwa
42
82886
Ibadan
13513
Ife
Ilaro
100651
2625
Shagamu
42
Ijebu Ode
LAGOS
97573
64530
Ikole
6484
Ado Ekiti
Ikere
4007
Akure
205
11389
Ikare
Owo
Ondo
15535
16742
Okitipupa
6971
Igarra
Agenebode
Idah
Auchi
Sabon Gida
2957
3045
Ubiaja
1204
5
Agbor
120
47885
SAPELE
16
2
WARRI
WARRI (Evac)
BIGHT OF BENIN
6
AWKA (Palmkr)
Onitsha
Awgu
16
Okigwi
16
Owerri
Umuahia
4116
Ahoada
25
16
Aba
2
Ikot Ekpene
4116
496
Yenagoa
6
PORT HARCOURT
6
Degema
4653
Itu
25
Akamkpa
25
CALABAR
7053
6940
Ikom
245
Ogoja
0
50
100 KILOMETRES
Railway Links
Road Links
Waterway Links
Volume of Flows (In Metric Tonnes)

FIGURE 43 MODAL COMPOSITION AND LINKAGE ALLOCATIONS OF COCOA SHIPMENTS TO IKEJA AND ONE MAJOR EXTERNAL DESTINATION OBTAINED FROM COST 2.

incurring transhipment costs to transfer to rail or waterway than continuing on the roads in this model.

6.2.8 Discussion on the Relative Changes in the Pattern of Cocoa Shipments Through the Ports

The results obtained from the models for shipping cocoa to one major destination indicate that the present pattern of demand for cocoa at the ports is inadequate with respect to the shipping bill incurred in cocoa shipments for export. Table 17 summarizes the actual quantities of cocoa shipped through the ports under the different formulations of the problem. The highest percentage of cocoa is actually demanded at both Lagos and Sapele ports. These two ports also have the highest proportion of shipments made through them to satisfy the demand at the external destination.

TABLE 17. PERCENTAGE OF COCOA SHIPMENTS THROUGH THE PORTS

Name of Port	Actual Demand at the Ports		Shipments to One Destination			
			Cost1 Demand		Cost2 Demand	
	Quantity	%Total	Quantity	%Total	Quantity	%Total
LAGOS	173753	78.5	127841	57.8	162103	73.2
P. H. PORT	8580	3.9	4715	2.1	4691	2.1
CALABAR	4444	2.0	7143	3.2	7053	3.2
SAPELE	34521	15.6	79859	36.1	47901	21.6

Whereas the percentage of cocoa shipped through Port Harcourt and Calabar ports to the external destination remained the same in both Cost1 and Cost2 Models (2.1% and 3.2%, respectively), the percentage of cocoa shipments through Lagos and Sapele ports changed. The quantity shipped through Lagos port increased from 57.8% in Cost1 Model to 73.2% in Cost2 Model while the quantity shipped through Sapele port decreased from 36.1% in Cost1 Model to 21.6% in Cost2 Model.

Table 18 shows the relative percentage of cocoa shipments when the demand at one external destination was considered. These were obtained by comparing the percentage of shipments through these ports in Cost1 and Cost2 Models to one major external destination with the actual percentage of shipments through these ports.

TABLE 18. RELATIVE PERCENTAGE OF COCOA SHIPMENTS THROUGH THE PORTS TO ONE MAJOR DESTINATION

	RELATIVE PERCENTAGE CHANGES	
NAME OF PORT	COST1 MODEL	COST2 MODEL
LAGOS	-20.7%	-5.3%
PORT HARCOURT	-1.8%	-1.8%
CALABAR PORT	+1.2%	+1.2%
SAPELE	+20.5%	+6.0%

There was a decrease in the relative percentage shipments through Lagos and Port Harcourt port in both models while there was an increase in these percentages at Calabar and Sapele ports. The magnitude of these percentage changes remained the same in Port Harcourt port and Calabar port in both models (-1.8% and +1.2%, respectively). The critical ports are Lagos and Sapele. The relative decrease in shipments through Lagos port was -20.7% in Cost1 model while the corresponding increase at Sapele port was +20.5%. In Cost2 Model, the magnitude of these changes were lower but they followed the same general trend.

Thus, the results of the analysis indicate that more saving in shipping bills will be made if demand for cocoa at Lagos port is reduced while the demand for cocoa at Sapele port is increased. The same findings apply to Port Harcourt port and Calabar port although to a lesser degree. The implications for these findings toward formulating a more efficient transport policy in Nigeria, and recommendations for future research resulting from these findings are discussed in the next chapter.

6.3 The Palm Kernel Shipping Problem

Palm kernels are produced in the southern forestlands of Nigeria and their area of production is more widespread than that of cocoa. In addition to large quantities of palm kernels exported annually through the ports, there are five palm kernel crushing mills that demand various quantities of this commodity. Three of these, Awka (Palmke), Orlu (Niproc) and Abak (Palmil) are located in the east while the other two Warri (Evoc) and Ikeja (Avoc) are located in the west. The freight rates or the cost of shipping one tonne of palm kernels on all available routes are the same as that for cocoa. The problem is to determine the pattern of shipping palm kernels to the ports in such a way that the total shipping bill of the Palm Produce Board is minimized and the pattern of shipments is optimal for the whole system.

6.3.1 Optimal Patterns of Palm Kernel Shipments to the Internal Demand Points and the Ports

The total shipping bill ($\sum \sum X_{ij} T_{ij}$) obtained from employing the road transport differential of the Palm Produce Board (Cost2) is higher by 2.5 percent than the cost obtained from the road freight rates of the carriers. Thus, the Board could have saved N63,799 on shipping palm kernels in 1976/77 if it had employed the services of the carriers instead of paying the licensed buying agents to undertake these shipments. Although the percentage saving is lower than that for cocoa shipments, the actual amount of savings is greater by N48,672 because larger quantities of palm kernels are involved.

The minimum cost flows of palm kernels between the producing regions and the demand points are the shipments (Xij's) that appear in the optimal solution. Cost1 Model has four alternative optimal solutions (Figures 44 to 47). These solutions consist of other combinations of shipments that have the same total cost on a system-wide basis. Figure 44 is the first optimal solution and is the pattern of shipment that is subsequently discussed. In the second alternative optimal solution (Figure 45), Okitipupa shipped to Sapele port instead of Owo shipping to Sapele port. In the third alternative optimal solution (Figure 46), Ikole instead of Owo shipped to Sapele port. In the fourth alternative optimal solution (Figure 47), Abudu shipped to Port Harcourt port instead of shipping to Warri port. These alternative shipments indicate that if Owo does not ship palm kernel to Sapele port, either Okitipupa or Ikole can ship to Sapele port at the same cost to the system. Also, Abudu can either ship to Warri port or Port Harcourt port at the same cost to the system.

Figures 44 and 48 illustrate the respective spatial pattern of palm kernel shipments when Cost1 and Cost2 are employed. Although there is the general tendency for the supply of palm kernels to the crushing mills and the ports to be made mostly from around the hinterland of these demand

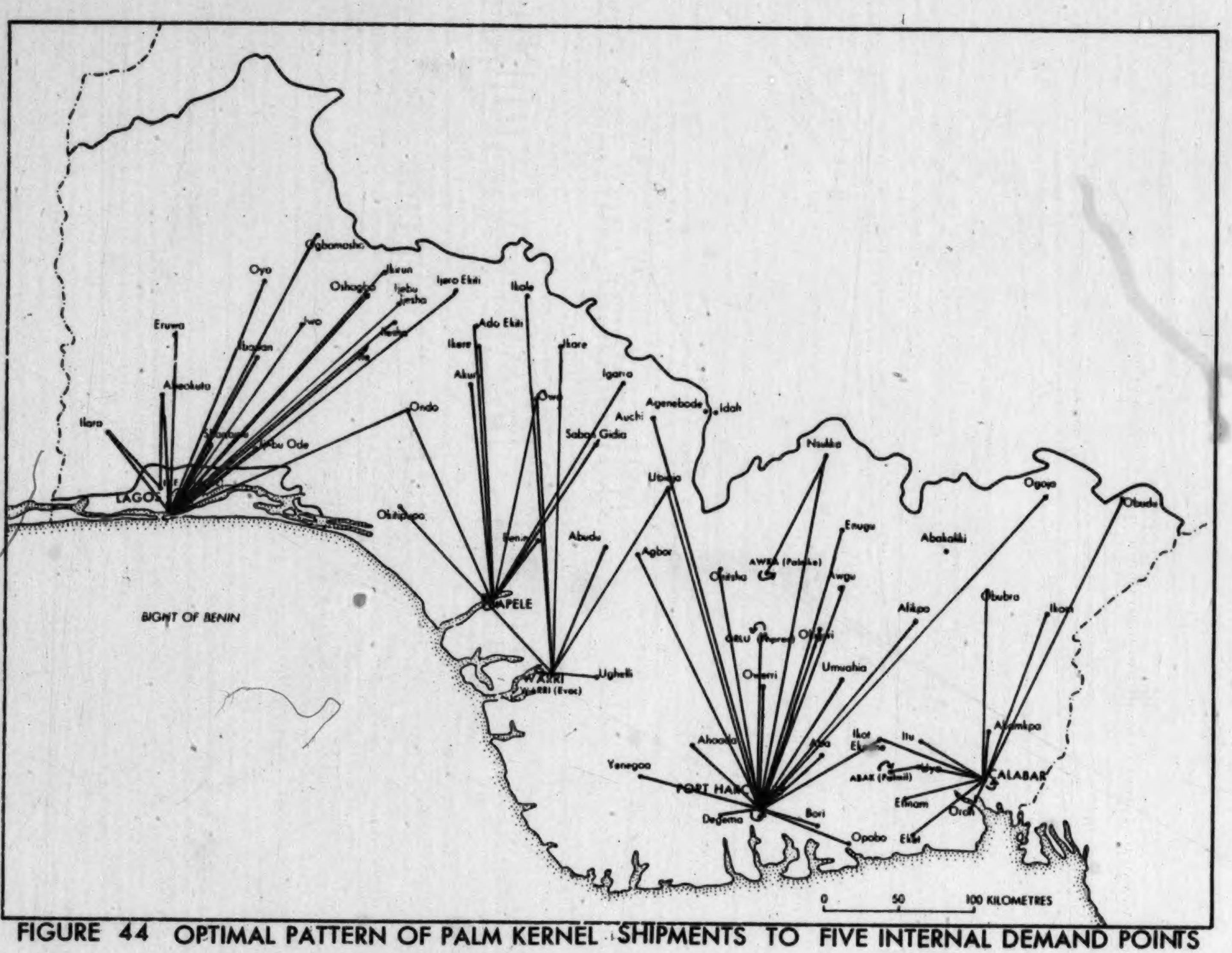
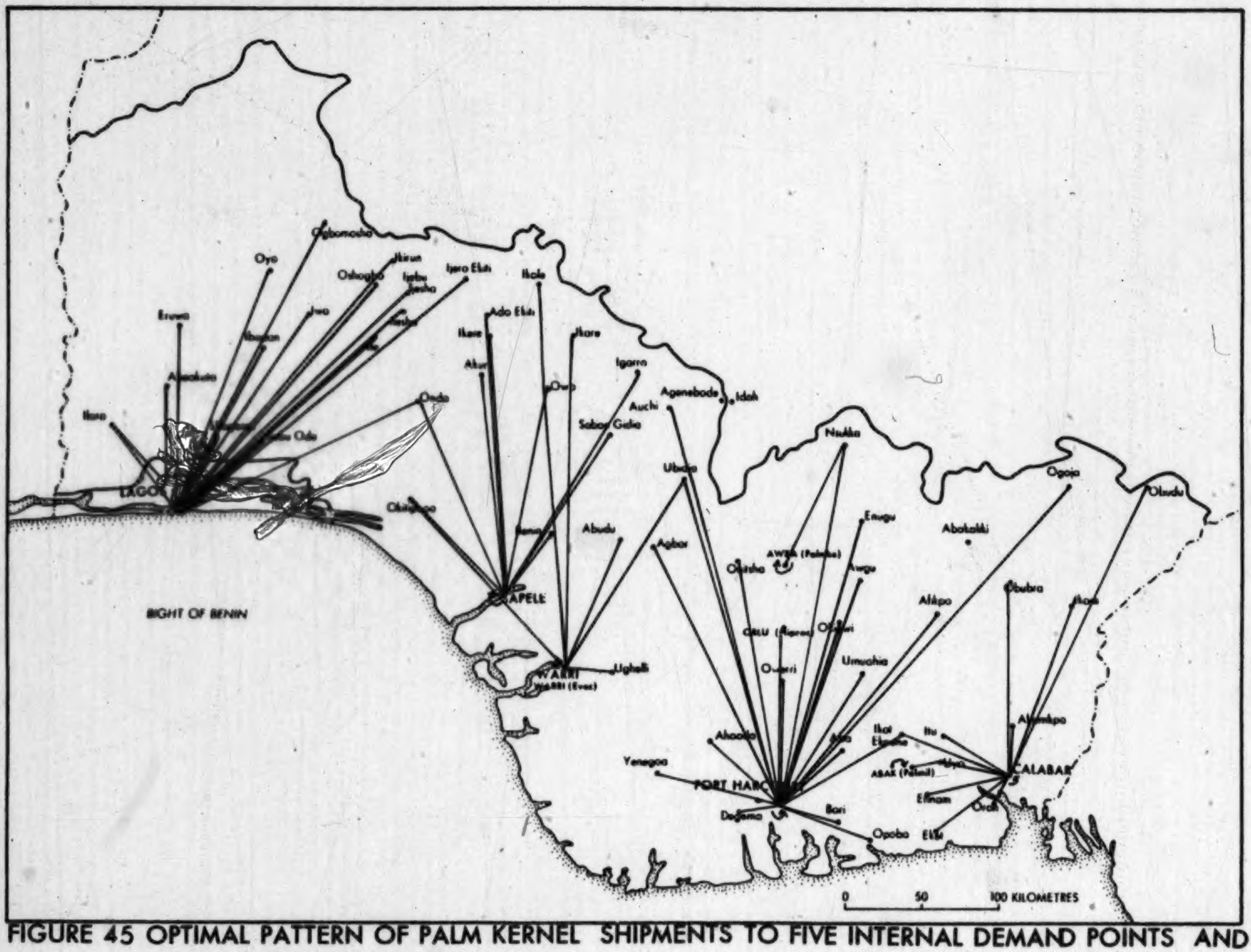

Ogbomosho
Oyo
Ikirun
Oshogbo
Ijebu
Ijesha
Ijero Ekiti
Ikole
Eruwa
Iwo
Ibadan
Ado Ekiti
Ikere
Ikare
Akure
Igarra
Abeokuta
Owo
Ondo
Agenebode
Idah
Auchi
Ilaro
Shagamu
Ijebu Ode
Sabon Gidia
Nsukka
Ubiaja
LAGOS
Okitipupa
Ogoja
Obudu
Enugu
Abakaliki
Benin
Abudu
Agbor
AWKA (Palmke)
Onitsha
Awgu
SAPELE
BIGHT OF BENIN
Obubra
Ikom
Alikpo
ORLU (Pepres)
Okigwi
WARRI
WARRI (Evac)
Ughelli
Umuahia
Owerri
Akamkpa
Ahoada
Aba
Ikot Ekpene
Itu
Uyo
Yenegoa
ABAK (Palmil)
CALABAR
PORT HARCOURT
Eket
Bori
Degema
Opobo
Oron
Etinam
0
50
100 KILOMETRES

FIGURE 44 OPTIMAL PATTERN OF PALM KERNEL SHIPMENTS TO FIVE INTERNAL DEMAND POINTS AND THE PORTS OBTAINED FROM COST 1. (I)



Ogbomosho
Oyo
Ikirun
Oshogbo
Ilesha
Ijero Ekiti
Ikole
Iwo
Eruwa
Ibadan
Ado Ekiti
Ikere
Ikare
Akure
Abeokuta
Owo
Igarra
Ondo
Ilaro
Ijebu Ode
Agenebode
Idah
Auchi
Sabon Gidie
LAGOS
Ubiaja
Nsukka
Okitipupa
Ogoja
Obudu
Abudu
Agbor
Enugu
Abakaliki
AWKA (Palmike)
Onitsha
Awgu
Obubra
Alkpo
Ikom
ORLU (Alarena)
Okigwi
BIGHT OF BENIN
SAPELE
WARRI
Ughelli
WARRI (Evas)
Owerri
Umuahia
Afikpo
Ahoada
Ikot Ekpene
Itu
Aba
Yenagoa
ABAK (Palmil)
CALABAR
PORT HARCOURT
Eket
Degema
Oron
Bori
Opobo
Eket
0
50
100 KILOMETRES

FIGURE 45 OPTIMAL PATTERN OF PALM KERNEL SHIPMENTS TO FIVE INTERNAL DEMAND POINTS AND THE PORTS OBTAINED FROM COST 1(II)

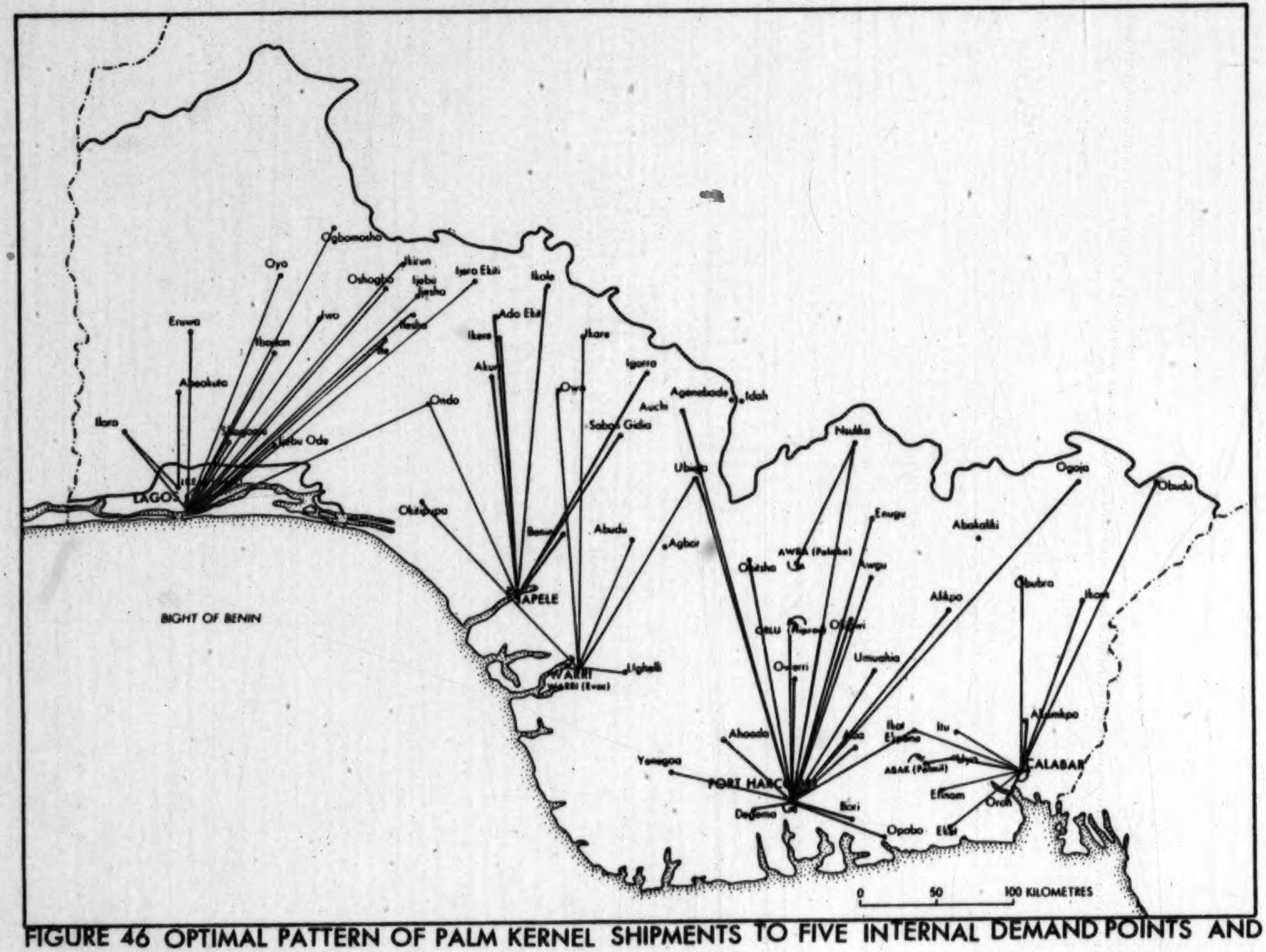

Ogbomosho
Oyo
Ikirun
Oshogbo
Ijebu Jesha
Ijero Ekiti
Ikole
Iwo
Ilesha
Eruwa
Ibadan
Ado Ekiti
Ikere
Ikare
Akure
Igarra
Abeokuta
Owo
Ondo
Agenebode
Idah
Auchi
Ilaro
Sabon Gidia
Ijebu Ode
Nsukka
Ubiaja
LAGOS
Okitipupa
Benin
Abudu
Agbor
Ogoja
Obudu
Enugu
Abakaliki
AWKA (Palmbe)
Onitsha
Awgu
Obubra
Ikom
Alikpo
APELE
BIGHT OF BENIN
ORLU
Okigwi
WARRI
Ughelli
WARRI (Evac)
Umuahia
Owerri
Akamkpo
Ahoada
Ikot Ekpene
Itu
Aba
Uyo
Yenagoa
ABAK (Palmol)
CALABAR
PORT HARCOURT
Eñnam
Oron
Degema
Bori
Opobo
Eket
0
50
100 KILOMETRES

FIGURE 46 OPTIMAL PATTERN OF PALM KERNEL SHIPMENTS TO FIVE INTERNAL DEMAND POINTS AND THE PORTS OBTAINED FROM COST 1 (III)

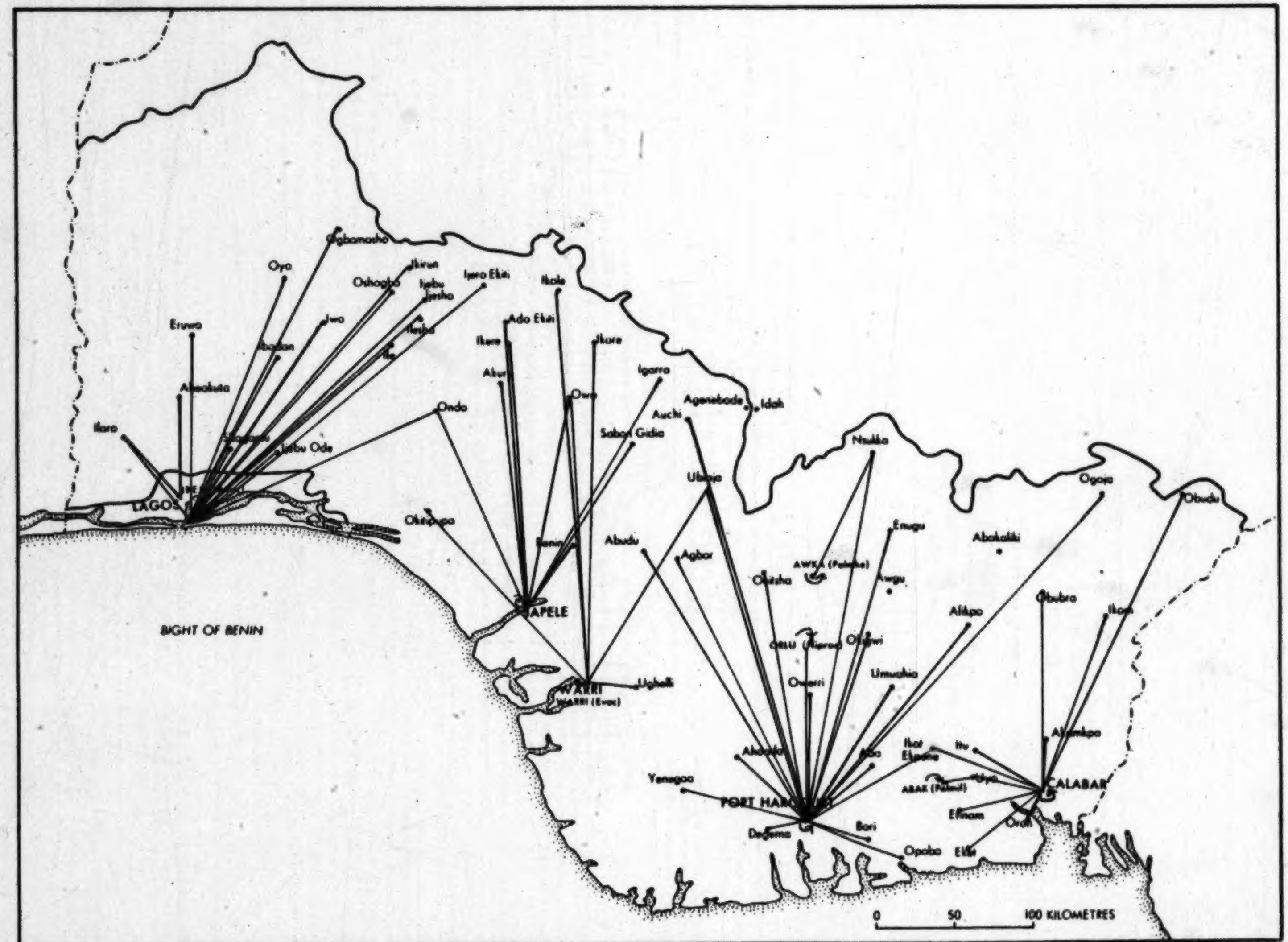

Ogbomosho
Oyo
Ikirun
Oshogbo
Ijebu
Ijesha
Ijero Ekiti
Ikole
Eruwa
Iwo
Ilesha
Ibadan
Ife
Ado Ekiti
Ikere
Ikare
Akure
Igarra
Owo
Abeokuta
Ondo
Agenebode
Idah
Auchi
Ilaro
Shagamu
Ijebu Ode
Sabon Gidia
Nsukka
Ubiaja
IRE
LAGOS
Okitipupa
Ogoja
Obudu
Benin
Abudu
Agbor
Enugu
Abakaliki
AWKA (Paloka)
Onitsha
Awgu
SAPELE
Obubra
Ikom
BIGHT OF BENIN
Alikpo
ORLU (Nkpor)
Okigwi
WARRI
Ughelli
WARRI (Evac)
Umuahia
Owerri
Akamkpa
Ikot Ekpene
Itu
Ahoada
Aba
Uyo
Yenagoa
ABAK (Palmil)
CALABAR
PORT HARCOURT
Eftnam
Oron
Degema
Bori
Opobo
Eket
0
50
100 KILOMETRES

FIGURE 47 OPTIMAL PATTERN OF PALM KERNEL SHIPMENTS TO FIVE INTERNAL DEMAND POINTS AND THE PORTS OBTAINED FROM COST 1 (IV)

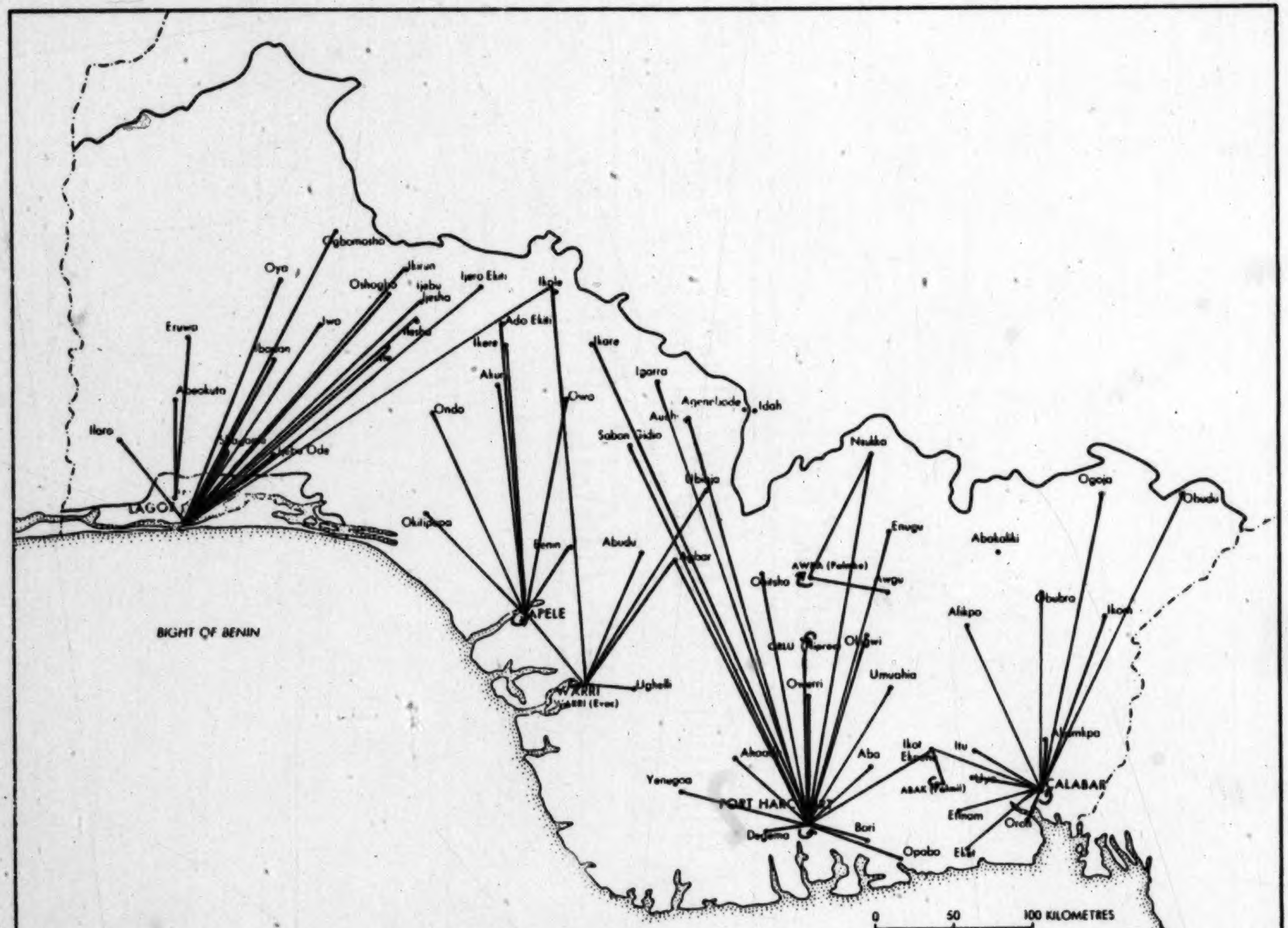

Ogbomosho
Oyo
Ikirun
Oshogbo
Ijebu
Ijesha
Ijero Ekiti
Ikole
Ilesha
Iwo
Eruwa
Ibadan
Ado Ekiti
Ikere
Ikare
Akure
Abeokuta
Ilaro
Ijebu Ode
LAGOS
Ondo
Owo
Igarra
Agenebode
Idah
Auchi
Saban Gidia
Ubiaja
Okitipupa
Benin
Abudu
Agbor
BIGHT OF BENIN
SAPELE
WARRI
WARRI (Evac)
Ughelli
Nsukka
Enugu
Abakaliki
AWKA (Palmike)
Onitsha
Awgu
ORLU
Okigwi
Owerri
Umuahia
Ahoada
Aba
Yenagoa
PORT HARCOURT
Degema
Bori
Opobo
Ikot Ekpene
ABAK (Palmil)
Itu
Ogoja
Obudu
Afikpo
Obubra
Ikom
Akamkpa
CALABAR
Eket
Oron
0
50
100 KILOMETRES

FIGURE 48 OPTIMAL PATTERN OF PALM KERNEL SHIPMENTS TO FIVE INTERNAL DEMAND POINTS AND THE PORTS OBTAINED FROM COST 2

points, there are several long cross-hauls involved.

As in the case of cocoa, the optimal shipments in both models are not strictly made to the least cost demand points of the producing regions nor did all supply regions ship to the same demand points in both models. For example, Ikole shipped to Warri port in Cost1 Model but to Lagos port in Cost2 Model. Ondo shipped partly to Sapele port and partly to Lagos port in Cost1 Model, but shipped entirely to Sapele port in Cost2 Model. Awgu shipped to Port Harcourt port in Cost1 Model but shipped to Awka (Palmke) in Cost2 Model. Ogoja, Afikpo and Akamkpa shipped to Port Harcourt port in Cost1 Model but all shipped to Calabar port in Cost2 Model.

Part of the demand for palm kernels at Abak (Palmil) was supplied from Uyo in Cost1 Model but this demand was supplied from Ikot Ekpene in Cost2 Model. Similarly, part of the demand for palm kernels at Ikeja (Avoc) was supplied from Ilaro in Cost1 Model but this demand was supplied from Eruwa in Cost2 Model.

In both models there are expensive long cross-hauls to Port Harcourt port. The spatial pattern of the optimal shipments (Figures 44 and 48) indicates the tendency for the hinterland of Port Harcourt to encroach on the hinterland of Calabar port in Cost1 Model, and the hinterlands of Warri and Sapele ports in Cost2 Model. This encroachment is such that in Cost1 Model, Ogoja, Akamkpa and Afikpo shipped to Port Harcourt port at higher costs (N1.42, N2.16 and N1.34 per tonne, respectivly) than shipping to Calabar port. In

Cost2 Model however, all three supply regions shipped optimally to Calabar port. Similarly, Auchi and Ubiaja shipped to Port Harcourt port at higher costs than shipping to Warri or Sapele ports in Cost1 Model while in Cost2 Model, Auchi in addition to Ikerre, Ikole, Sabongida Ora, and Igarra shipped to Port Harcourt port. All these shipments to Port Harcourt port were made at higher costs ranging from N2.31 to N6.30 per tonne than shipping to either Warri port or Sapele port.

In both models, most of the shipments to Warri port could have been made to Sapele port at a lower cost. For example, shipments from Okitipupa, Agbor and Abudu to Warri port in Cost1 Model and from Abudu to Warri port in Cost2 Model are more expensive than shipments to Sapele port in each case. In the same way, shipments to Lagos port from Ife, Iwo, Ondo, Ilesha and Ijero Ekiti could have been made to either Sapele or Warri port at a lower cost. Thus, there are several costly shipments of palm kernels which are made in order to satisfy the demand at the ports.

There are also other costly shipments that were made in order to satisfy the demand for palm kernels at the internal demand points. It would have been cheaper for Ikot Ekpene and Uyo in Cost1 Model and for Uyo, Obudu, Ikom and Itu to ship to Abak (Palmil) than for these supply regions to ship to Calabar port. Awgu shipped at a higher cost of N2.03 per tonne to Port Harcourt port in Cost1 Model than shipping to Awka (Palmke) but in Cost2 Model it ships to Awka whereas it would have been slightly cheaper if it had shipped to Orlu (Niproc). In both models, Enugu, Onitsha, Owerri and Nsukka shipped to Port Harcourt port whereas it would have been cheaper if they had shipped to Awka (Palmke) or Orlu (Niproc).

Further south, Okigwi and Awgu in Cost1 Model and Umuahia and Okigwi in Cost2 Model shipped to Port Harcourt port at higher costs than shipping to either Orlu (Niproc) or Abak (Palmil). Also, Afikpo and Ikot Ekpene could have shipped to either Orlu or Abak at a cheaper cost than their respective shipments to Calabar and Port Harcourt ports in Cost2 Model. All the costly shipments to these demand points may have been made in order to satisfy the high demand for palm kernels at the ports or due to insufficient demand for this commodity at the crushing mills.

6.3.2 Optimal Dual Solution of Palm Kernel Shipments to Internal Demand Points and the Ports

Supply regions with high relative values of ui are those regions that are more favourably located for producing palm kernels. Therefore, the Palm Produce Board will incur lower shipping bills if the supply capacity for palm kernels were increased in such areas. Figure 49 illustrates that in Cost1 Model, there is the tendency for the areas with the highest ui values to be concentrated around the seaports, namely, Calabar, Port Harcourt, Warri and Sapele. Thus, the expansion of palm kernel production in such areas will

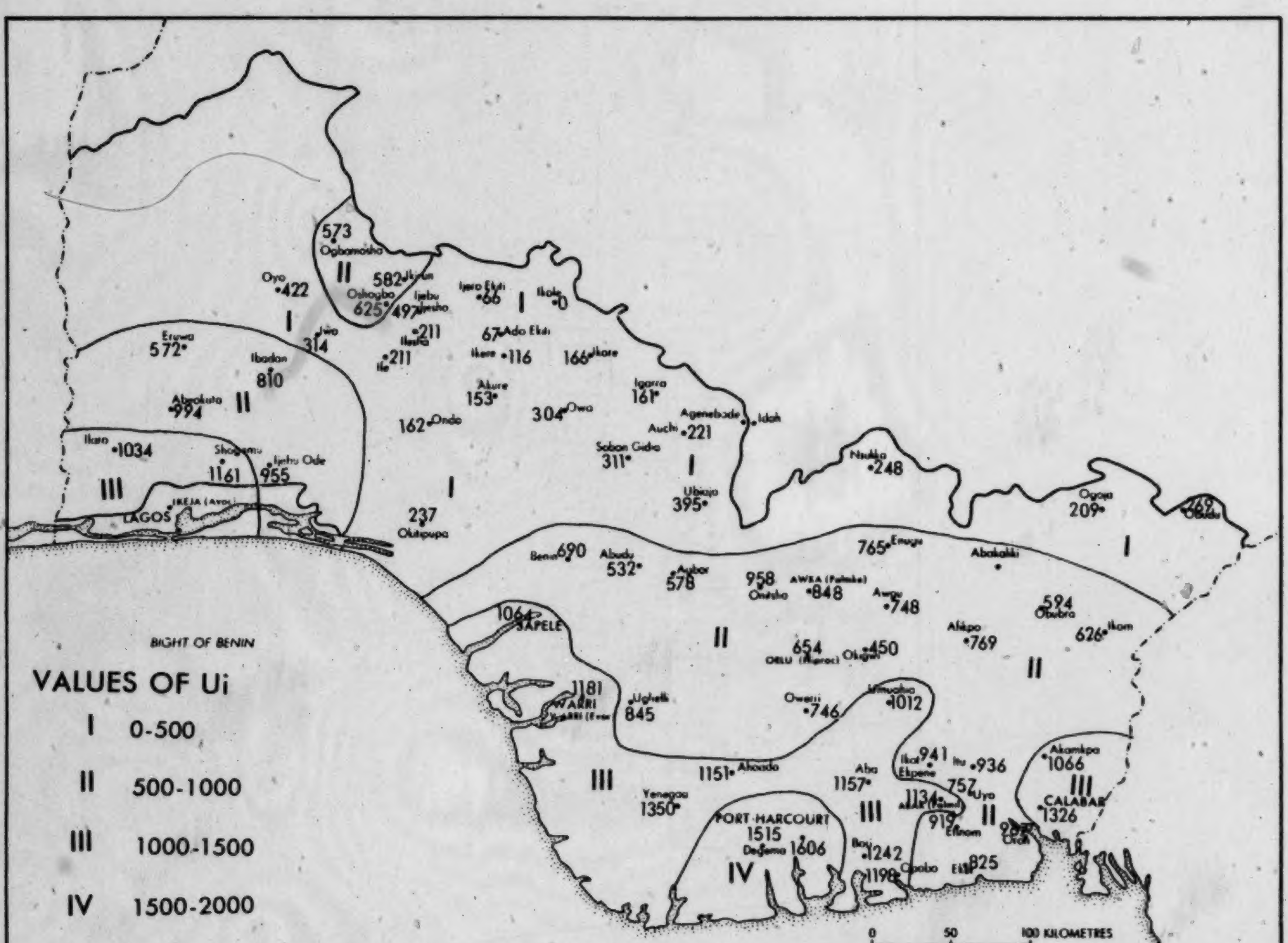

573
Ogbomosho
II
582 Ikirun
Oshogbo
625
497 Ijebu Ijesha
Oyo
422
I
Iwo
314
Eruwa
572
Ibadan
810
Abeokuta
994
II
Ilaro
1034
Shagamu
1161
Ijebu Ode
955
III
IKEJA (Ayo)
LAGOS
Ijero Ekiti
66
Ikole
0
211
Ilesha
211
Ile
67 Ado Ekiti
Ikere 116
166 Ikare
Akure
153
162 Ondo
304 Owo
Igarra
161
Agenebode
Idah
Auchi
221
Sabon Gidda
311
Ubiaja
395
237
Okitipupa
Nsukka
248
Ogoja
209
269
Obudu
Benin 690
Abudu
532
Agbor
578
958
Onitsha
AWKA (Pulmike)
848
765 Enugu
Abakaliki
Awgu
748
594
Obubra
626 Ikom
Afikpo
769
654
ORLU (Ifuproc)
Okigwi
450
1064
SAPELE
1181
WARRI
WARRI (Free)
Ughelli
845
Owerri
746
Umuahia
1012
III
1151 Ahoada
Yenagoa
1350
PORT HARCOURT
1515
Degema 1606
IV
Aba
1157
III
Bori
1242
1198
Opobo
Ikot Ekpene
941
Itu
936
1134
ABAK (Pulmil)
757 Uyo
919
Eftnom
II
Eket
825
Oron
Akamkpa
1066
III
CALABAR
1326
BIGHT OF BENIN
VALUES OF Ui
I 0-500
II 500-1000
III 1000-1500
IV 1500-2000
0
50
100 KILOMETRES

FIGURE 49 OPTIMAL DUAL SOLUTION OF PALM-KERNEL SHIPMENTS TO FIVE INTERNAL DEMAND POINTS AND THE PORTS OBTAINED FROM COST 1

result in the greatest savings in shipping bill for the Palm Produce Board. The savings in shipping bill to be incurred decreases from these ports towards the interior.

Port Harcourt port with the highest ui value of 1606 is the most favourably located supply point for increasing the supply capacity of palm kernel whereas the area around Ikole, Ijero Ekiti and Ado Ekiti is most unfavourably located for expanding the supply of palm kernel since these supply points have the lowest ui values. Therefore, the Board will incur the greatest saving in shipping bills if palm kernel supply were increased at Port Harcourt and surrounding areas.

In Cost2 Model (Figure 50), the values of ui are still highest in the south, and decrease towards the interior but the concentration of lowest values around the ports is not as distinct as in the model obtained from Cost1. Port Harcourt port and Calabar port and their immediate hinterlands have the highest relative values of ui. These values decrease toward the wide region directly above them which includes Sapele and Warri ports. Whereas Port Harcourt port had the highest ui value (1606) in Cost1 Model, it was Calabar port that had the highest ui value of 2469 in Cost2 Model. These relationships influence the relative costs of increasing demand capacity at both ports in the models. As in Cost1 Model, the area with the lowest relative values of ui occur around Ikole, Ijero Ekiti and Ado Ekiti although this area is more extensive in Cost1 Model than in Cost2

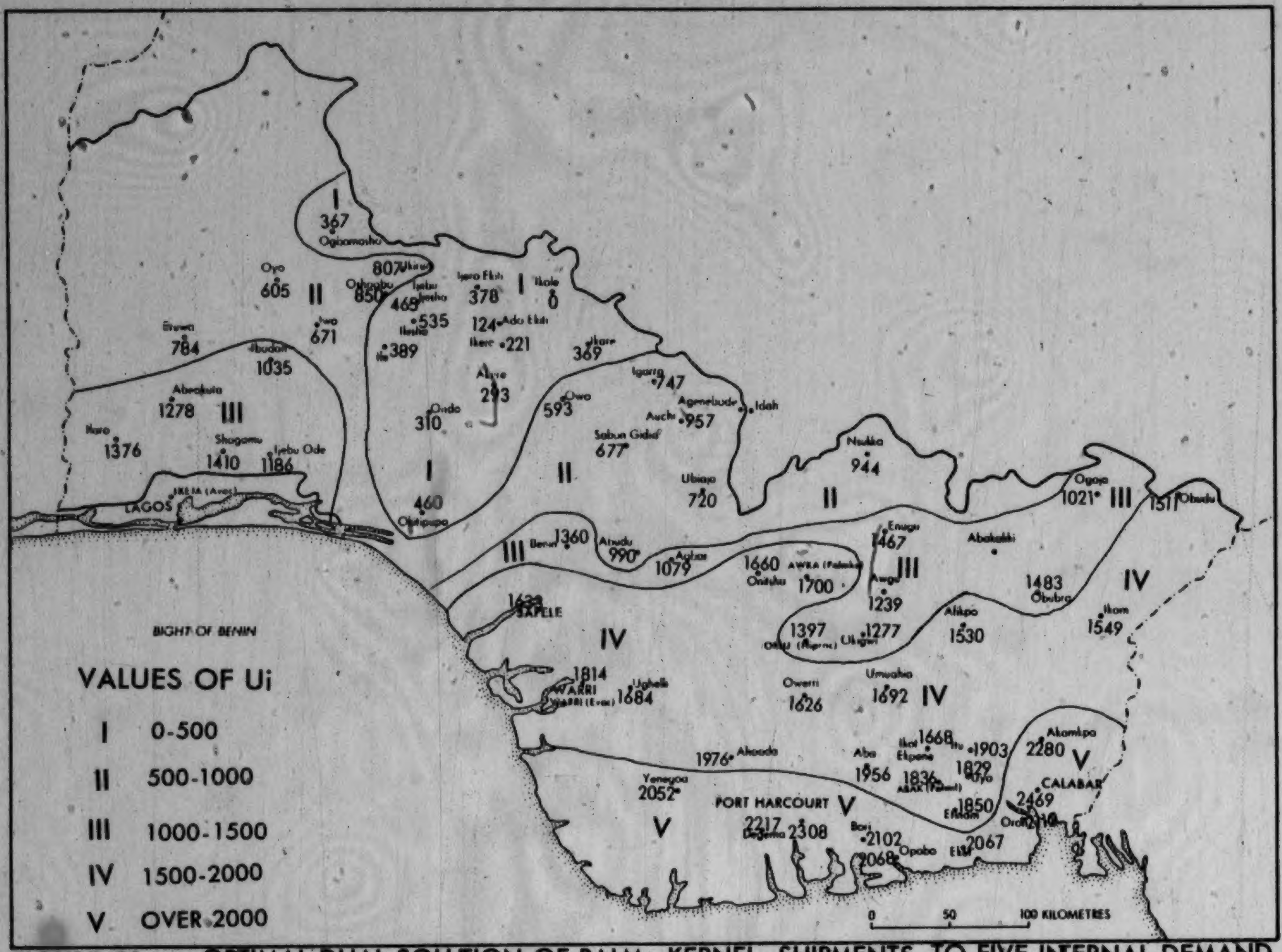

VALUES OF Ui
I 0-500
II 500-1000
III 1000-1500
IV 1500-2000
V OVER 2000
BIGHT OF BENIN
0 50 100 KILOMETRES
I
367
Ogbomosho
Oyo
605
II
807
850
Oshogbo
Iwo
671
Ilesha
465
535
Ife
389
Igbo Ekiti
378
I
Ikole
0
124 Ado Ekiti
Ikere 221
Ikare
369
Akure
293
Ondo
310
I
460
Okitipupa
Eruwa
784
Ibadan
1035
Abeokuta
1278
III
Ilaro
1376
Shagamu
1410
Ijebu Ode
1186
IKEJA (Apapa)
LAGOS
Owo
593
II
Igarra
747
Agenebode
Idah
Auchi
957
Sabun Gida
677
Ubiaja
720
III
Benin
1360
Abudu
990
Agbor
1079
1660
Onitsha
AWKA (Palmol)
1700
1639
SAPELE
IV
1814
WARRI
WARRI (Evas)
Ughelli
1684
Nsukka
944
II
Enugu
1467
Awgu
III
1239
1397
Okigwi
1277
Ogoja
1021
III
1511
Obudu
Abakaliki
1483
Obubra
IV
Afikpo
1530
Ikom
1549
Owerri
1626
Umuahia
1692
IV
1976 Ahoada
Aba
1956
Ikot Ekpene
1668
Itu
1903
1836
ABAK (Palmol)
1829
Uyo
1850
Eket
Akamkpa
2280
V
CALABAR
2469
Oron
2110
Yenagoa
2052
V
PORT HARCOURT
V
2217
Degema
2308
Bori
2102
2068
Opobo
Eket
2067

FIGURE 50 OPTIMAL DUAL SOLUTION OF PALM-KERNEL SHIPMENTS TO FIVE INTERNAL DEMAND POINTS AND THE PORTS OBTAINED FROM COST 2.

Model. The Palm Produce Board will incur higher shipping bill if supply of palm kernels were increased in this area.

The vj's indicate the relative cost of increasing the demand capacity for palm kernels among the vj's or destinations. Table 19 illustrates the relative costs of changing the demand capacity for palm kernels at all the demand points. Orlu (Niproc) with a vj value of 804 in Cost1 Model and 1547 in Cost2 Model is the least expensive demand point for increasing the demand capacity for palm kernels. Apart from this demand point that had the same relative value as a demand point in both models, the comparative locational value of all the other demand points for palm kernels changed in both models. This is contrary to the results of the cocoa shipping problem, where the comparative locational value of all the demand points remained unchanged in the two models.

In Cost1 Model, Port Harcourt port (vj =1701) and Lagos port (vj = 1661) are the most costly ports for increasing the demand for palm kernels, while Sapele port (vj = 1155) is the least expensive port for increasing the demand for palm kernels. To increase the demand for palm kernels at Port Harcourt port will cost the Board 284 (1701 - 1417 = 284), more than increasing demand at Calabar. It is also more expensive to increase demand at Lagos port than to increase demand at Warri and Sapele ports. These indicate that the Palm Produce Board will incur higher shipping bills if demand capacity for palm kernels were increased at Lagos

TABLE 19.THE DEMAND DUAL SOLUTION OF PALM KERNEL SHIPPING PROBLEM TO INTERNAL DEMAND POINTS AND THE PORTS

A.

NAME OF DEMAND POINT	VJ IN COST1
PORT HARCOURT PORT	1701
LAGOS PORT	1661
IKEJA (Von)	1650
CALABAR PORT	1417
WARRI PORT/EVOC	1272
ABAK (Palmil)	1225
SAPELE PORT	1155
AWKA (Palmke)	1098
ORLU (Niproc)	804

B.

NAME OF DEMAND POINT	VJ IN COST2
CALABAR PORT	2560
PORT HARCOURT PORT	2403
AWKA (Palmke)	1950
IKEJA (Von)	1934
ABAK (Palmil)	1927
WARRI PORT/EVOC	1923
LAGOS PORT	1886
SAPELE PORT	1724
ORLU (Niproc)	1547

and Port Harcourt ports than if demand were increased at Calabar, Sapele and Warri ports. These results are similar to the results of the cocoa shipping problem in which Port Harcourt and Lagos ports were the most costly ports for expanding demand.

The results obtained from the Cost2 Model for the palm kernel shipping problem is quite different and indicate that Calabar port (vj = 2560) is the most costly port for expanding demand than all the other ports in the system. Cost2 Model suggests that in order to reduce the shipping bill of the Palm Produce Board, the demand capacity at Port Harcourt, Lagos, Sapele and Warri ports but not Calabar port should be increased.

Port Harcourt is the most costly demand point for increasing the demand for palm kernels in Cost1 Model while Calabar port is the most costly demand point for increasing demand in Cost2 Model. These demand points were also the most favourable supply points in the respective models since the Board would be saving most on shipping bills if it expanded production in the most costly demand points.

Ikeja (Von) is the most expensive internal demand point for increasing the demand for palm kernels in Cost1 Model. To increase the demand for palm kernels at Ikeja will cost more by 425, 846, and 552 than expanding the demand at Abak (Palmil), Orlu (Niproc) and Awka (Palmke), respectively. In Cost2 Model, Awka (Palmke) and Ikeja (Von) are the most costly internal demand points. In both models, Orlu (Niproc) is the least costly internal demand point for palm kernels and the Palm Produce Board would save shipping bills if the demand capacity at this processing mill were increased.

On the whole, it would seem that the apparently sub-optimal shipments of palm kernels may have been caused by insufficient demand for palm kernels at the demand points, especially, Calabar, Sapele, and Warri ports in Cost1 Model and all the other ports except Calabar in Cost2

Model. Insufficient demand capacity for palm kernels in all the processing mills except Ikeja in Cost1 Model and all the mills in Cost2 Model also cause apparently sub-optimal shipments of palm kernels which are very expensive to be made.

The relative costs of increasing demand capacity for palm kernels at these demand points indicate that some savings on the shipping bill of the Palm Produce Board could be made by adjusting the existing allocation of palm kernels at the ports. The relationships obtained from comparing the relative costs of increasing demand capacity at the ports are further investigated when the demand at one external destination or the outside world is considered.

6.3.3 Modal Composition and Linkage Allocation of Palm Kernel Shipments to Internal Demand Points and the Ports

Improper selection of the most economical mode of transporting palm kernels to the demand points may give rise to inefficiencies in the system. The model allows for inter-modal transfers at the expense of the appropriate transhipment cost. Figures 51 and 52 illustrate the spatial pattern of modal composition and volume of shipments along the links which were obtained from Cost1 and Cost2, Models, respectively. As in the case of cocoa, Cost1 Model makes greater use of the road than rail or river. In this model (Figure 51), only the supply regions located along the Western Railway District shipped by rail to Lagos port. In

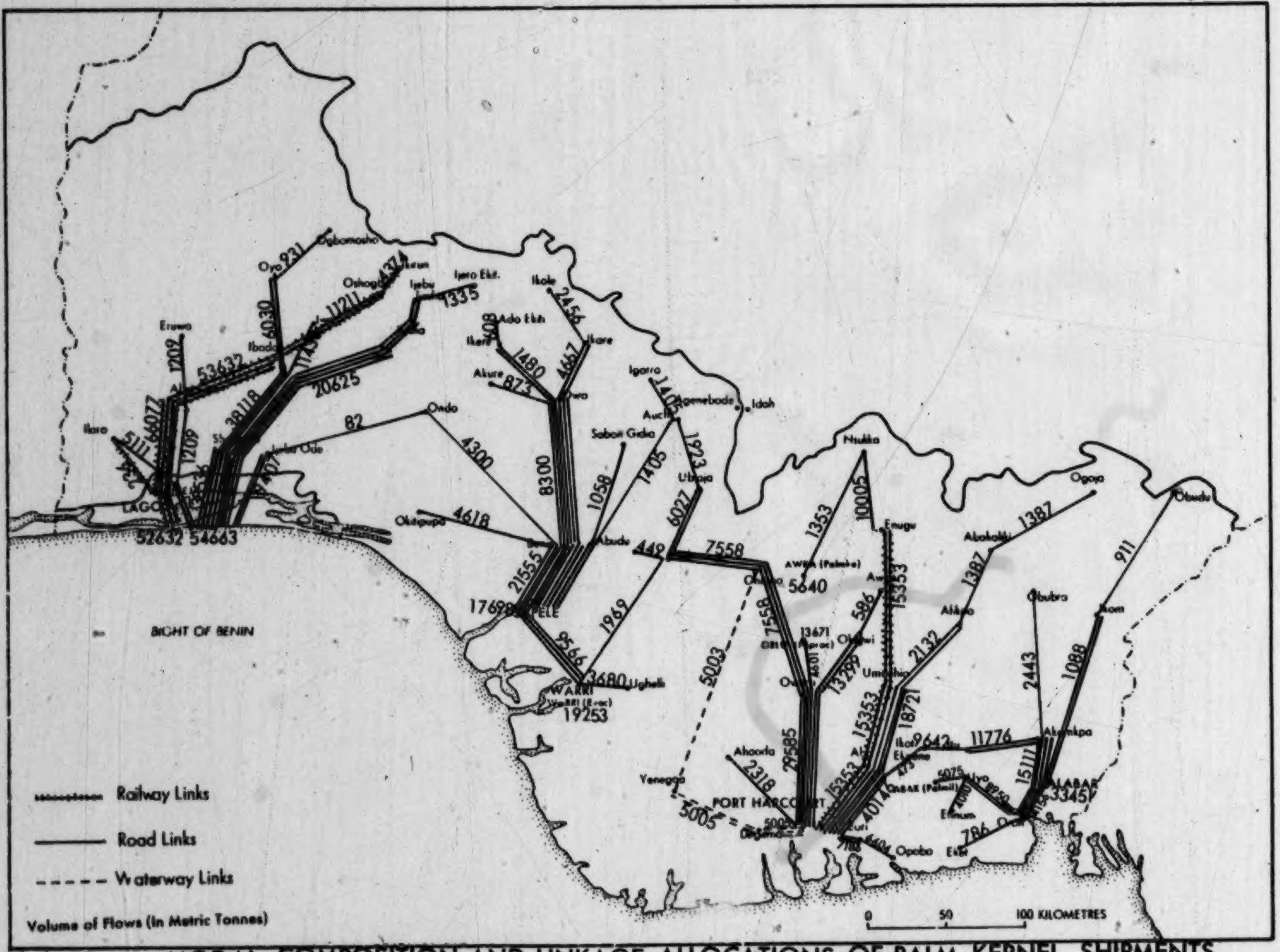

Ogbomosho
Oyo 931
Oshogbo
4374
11211
6030
Ijebu
Ipero Ekit.
1335
Erewa
1209
Ibadan
53632
38118
20625
Ilaro
5111
66077
82
Ondo
4300
Ijebu Ode
LAGOS
52632 54663
Okitipupa
4618
Ikole
2456
Ado Ekiti
Ikere
1480
4667
Ikare
Akure
873
8300
1058
Sobon Gidia
1405
Igarra
1402
Agenebode
Idah
Auchi
1923
Ubiaja
6027
21555
Abudu
449
7558
17692
SAPELE
9566
1969
3680
Ughelli
WARRI
19253
BIGHT OF BENIN
5003
Yenagoa
5005
Nsukka
10005
1353
Enugu
AWKA (Palmina)
5640
13671
Onitsha
15353
586
13299
Umuahia
Ahoada
2318
29585
PORT HARCOURT
15353
2132
18721
Abakaliki
1387
1387
Ogoja
Obudu
911
Afikpo
Obubra
Ikom
2443
1088
9642
11776
Akampka
15111
CALABAR
3345
Opobo
786
Eket
Railway Links
Road Links
Waterway Links
Volume of Flows (In Metric Tonnes)
0
50
100 KILOMETRES

FIGURE 51 MODAL COMPOSITION AND LINKAGE ALLOCATIONS OF PALM KERNEL SHIPMENTS TO FIVE INTERNAL DEMAND POINTS AND THE PORTS OBTAINED FROM COST 1.

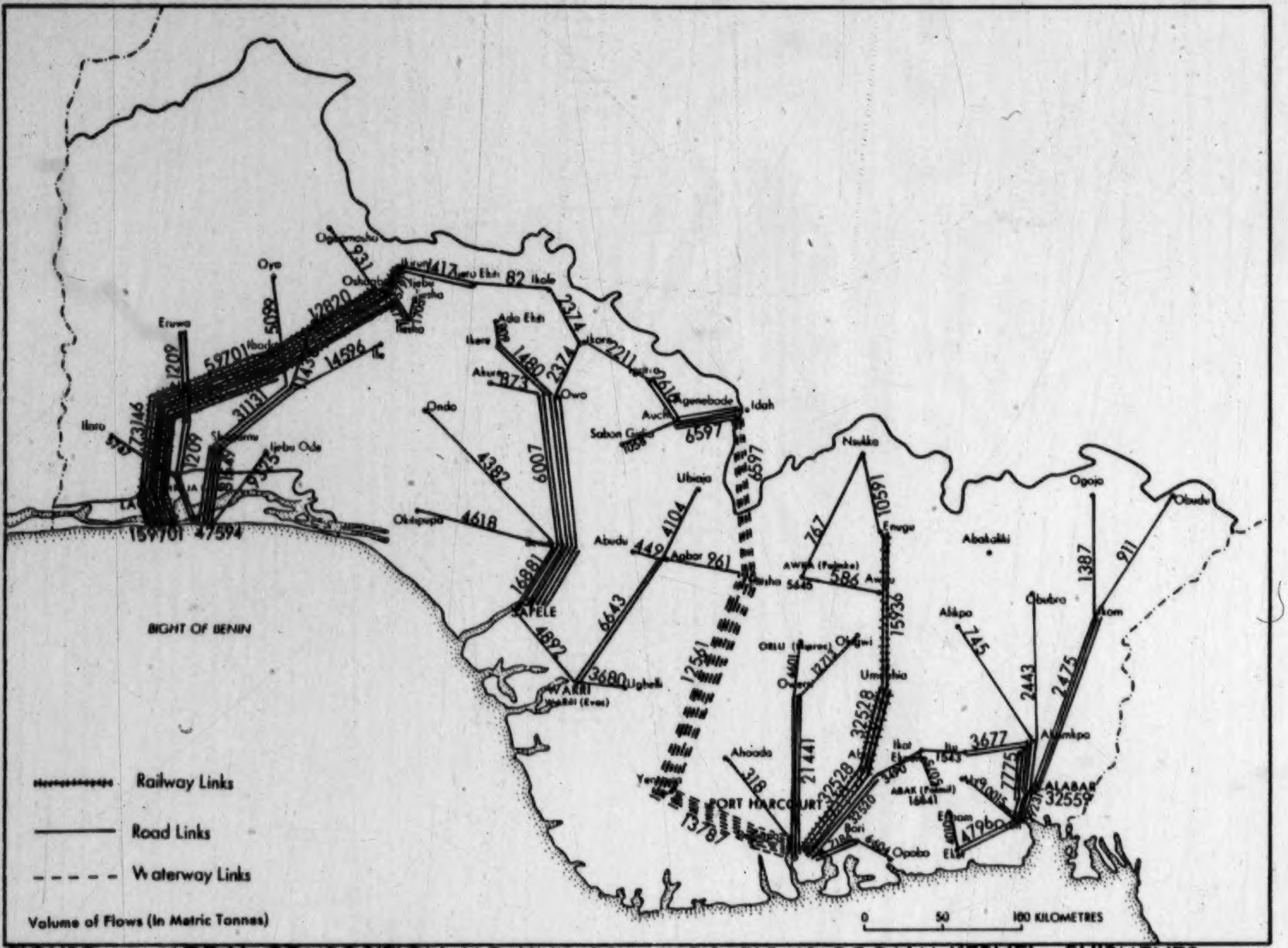

Oyo
5099
Ogbomosho
931
Oshogbo
12820
Ilesha
1417
Ado Ekiti
82
Ikole
2374
Eruwa
1209
59701
Ibadan
14596
Ife
1430
3113
Ilaro
73146
Shagamu
1209
Ijebu Ode
3375
159701
47594
Ikere
1480
Akure
873
2374
Owo
Ondo
4382
6007
Okitipupa
4618
16881
SAPELE
4892
WARRI
6643
3680
Ughelli
Abudu
449
Agbor
961
4104
Ubiaja
Ikare
2211
2616
Agenebode
Idah
Auchi
6597
Sabon Gida
1058
6597
Onitsha
12561
13787
Yenagoa
Nsukka
767
10591
Enugu
AWKA (Palmke)
586
Awgu
15936
Umuahia
32528
ORLU (Emeroc)
Okigwi
Owerri
21441
Ahoada
318
PORT HARCOURT
32528
Bori
Opobo
Ikot Ekpene
Itu
1543
3677
ABAK (Palmil)
1664
Eket
Eket
47960
Alikpo
745
Obubra
2443
Ogoja
1387
Ikom
911
2475
Obudu
Abakaliki
7775
Akamkpa
CALABAR
32559
BIGHT OF BENIN
Railway Links
Road Links
Waterway Links
Volume of Flows (In Metric Tonnes)
0
50
100 KILOMETRES

FIGURE 52 MODAL COMPOSITION AND LINKAGE ALLOCATIONS OF PALM KERNEL SHIPMENTS TO FIVE INTERNAL DEMAND POINTS AND THE PORTS OBTAINED FROM COST 2

the Eastern Railway District, it was only Enugu that shipped to Port Harcourt port by rail while Aba and Umuahia located along the railway shipped to Port Harcourt port by road. This may indicate that the road transport freight rates of the carriers are less expensive than rail shipments for very short distances. There were no transhipments to the River Niger in this model and only Onitsha, Yenegoa and Degema located along the river shipped to Port Harcourt port by waterway.

Cost2 Model (Figure 52) indicates greater use of the railway and waterway. All shipments to Port Harcourt port from Sabongida Ora, Igarra, Ikare, and Auchi transhipped to the waterway at Agenebode. In addition to these, Onitsha, Yenegoa and Degema along the River Niger shipped to Port Harcourt port by waterway. All the supply regions along both the Western and the Eastern Railway Districts shipped by rail to Lagos port and Port Harcourt port, respectively. In addition to these, five other centers (Ikole, Ijero Ekiti, Ilesha, Ijebu Ijesha and Ogbomosho) transhipped to the railway at either Ikirun or Oshogbo. All the shipments by rail were long-hauls which are less expensive than the short-hauls.

The fact that greater use is made of the cheaper railways and waterways in this model may indicate that the road transport differential of the Palm Produce Board is expensive forcing those shipments that began on the roads to transfer to cheaper modes. Thus, while the model suggested that 49.1 percent of palm kernel shipments to Lagos port should be made by rail in Cost1 Model, it suggested that over 55 percent of these shipments should be made by rail in Cost2 Model.

6.3.4 Palm Kernel Shipments to the Internal Demand Points and One Major External Destination

The optimal pattern of palm kernel shipments represents the system of shipments that could have been achieved by the Palm Produce Board in 1976/77. Under this programme, the regional production of palm kernels and the demand for this commodity at the processing mills and the ports were fixed. It has been indicated that these fixed demands of palm kernels were forcing some apparently sub-optimal shipments involving higher costs to be made.

The demand for palm kernels at the ports are made in order to satisfy the demand for Nigerian palm kernels at the foreign markets. It would therefore, be meaningful to compare the results of the models obtained from the port demand for this commodity with the pattern of demand that would minimize total shipping bills from the supply regions directly to the external destinations or foreign markets.

In order to do this, the palm kernel shipping problem was reformulated and solved again in order to investigate the effect of the fixed demand for palm kernels at the ports. The new formulation was designed to indicate whether the pattern of port demands for this commodity could be adjusted to enable a more efficient internal shipping pattern to be made and still satisfy the demand for Nigerian palm kernels in the foreign markets.

All the demands for palm kernels at the seaports were added together and assumed to be equivalent to the demand for Nigerian palm kernels at one major external destination. These ports, now having zero demand, were treated as transhipment points and were connected to the major external destination by links of equal cost. A nominal cost of N1.00 per tonne was employed and was later subtracted from each solution in this formulation in order to make them comparable with the earlier models. This formulation emphasizes the important assumption that the Palm Produce Board can ship palm kernels to any port within the country in order to minimize shipping bill and increase its net financial surplus.

6.3.5 Optimal Patterns of Palm Kernel Shipments to the Internal Demand Points and One Major Destination

The total shipping bill ($\sum \sum X_{ij} T_{ij}$) obtained from Cost2 Model is 6.6 percent higher than that obtained from Cost1 Model. This means that the Palm Produce Board could have saved N162,100 on the transportation of palm kernels if the demands at the ports were adjusted and the Board employed the services of the carriers instead of paying the licenced buying agents to undertake these shipments in 1976/77. This means that if it is assumed that the Palm

Produce Board were already employing the services of the road transport carriers for transporting palm kernels to the demand points, it would have saved an additional 4.1 percent of its former costs if the port demands were also adjusted.

The total shipping bill ($\sum \sum Xij\ Tij$) obtained from both reformulated models were lower than their corresponding models in the earlier formulation. The total bill from Cost1 Model involving the internal destinations and one major external destination is 94.6 percent of the earlier model while the total bill from Cost2 Model in this formulation is 98.4 percent of the earlier model. As in the case of cocoa shipments, this reformulation results in greater savings in shipping bill for Cost1 Model (N141,789) than for Cost2 Model (N43,488). This indicates that in terms of the road transport differential of the Palm Produce Board, the existing demand for palm kernels at the ports in relation to the demand for Nigerian palm kernels at the external market was only 1.6 percent inefficient while the same system was 5.4 percent inefficient in terms of the road freight rates of the carriers. As in the case of cocoa, the rates set by the Board are more oriented to satisfy the existing port demand for palm kernels than the rates set by the transport firms.

The spatial pattern of shipments (Figures 53 and 54) indicates the tendency for the supply regions shipping through each port to the external destination to be concentrated in the immediate hinterlands about these ports.

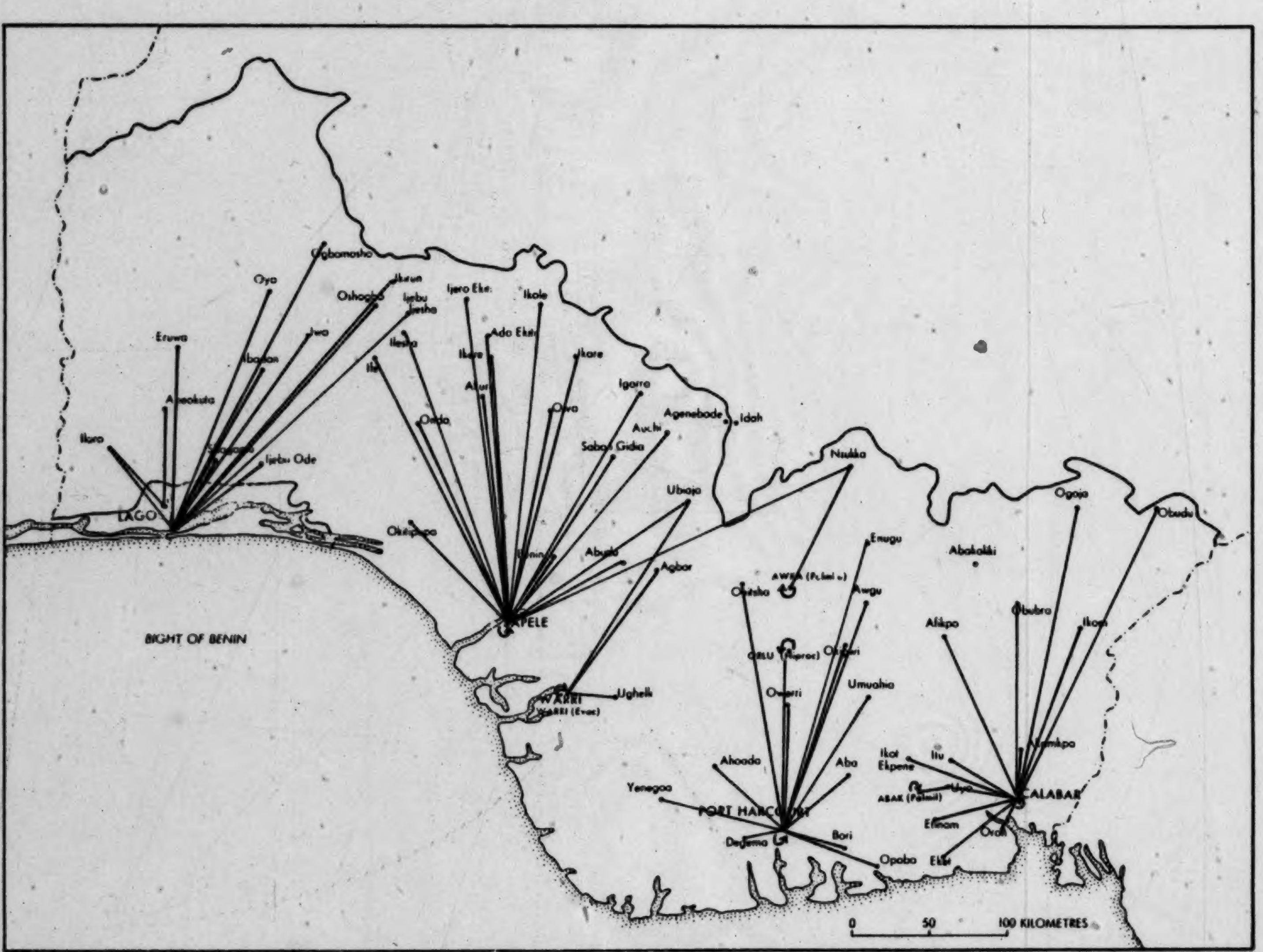

Ogbomosho
Oyo
Ikirun
Oshogbo
Ijebu
Ijesha
Eruwa
Iwo
Ibadan
Abeokuta
Ilaro
Ijebu Ode
LAGOS
BIGHT OF BENIN
Ijero Eke.
Ikole
Ado Ekiti
Ilesha
Ikare
Ikare
Akure
Owo
Igarra
Ondo
Agenebode
Idah
Auchi
Sabon Gidda
Ubiaja
Okitipupa
Benin
Abudu
Agbor
SAPELE
WARRI
WARRI (Evac)
Ughelli
Nsukka
Enugu
Abakaliki
AWKA (Pulmil)
Onitsha
Awgu
ORLU (Pioneer)
Okigwi
Owerri
Umuahia
Ahoada
Aba
Yenegoa
PORT HARCOURT
Degema
Bori
Opobo
Ogoja
Obudu
Obubra
Afikpo
Ikom
Akamkpa
Ikot Ekpene
Itu
Uyo
ABAK (Palmil)
CALABAR
Efinam
Oron
Eket
0
50
100 KILOMETRES

FIGURE 53 OPTIMAL PATTERN OF PALM KERNEL SHIPMENTS TO FIVE INTERNAL DEMAND POINTS AND ONE MAJOR EXTERNAL DESTINATION OBTAINED FROM COST 1

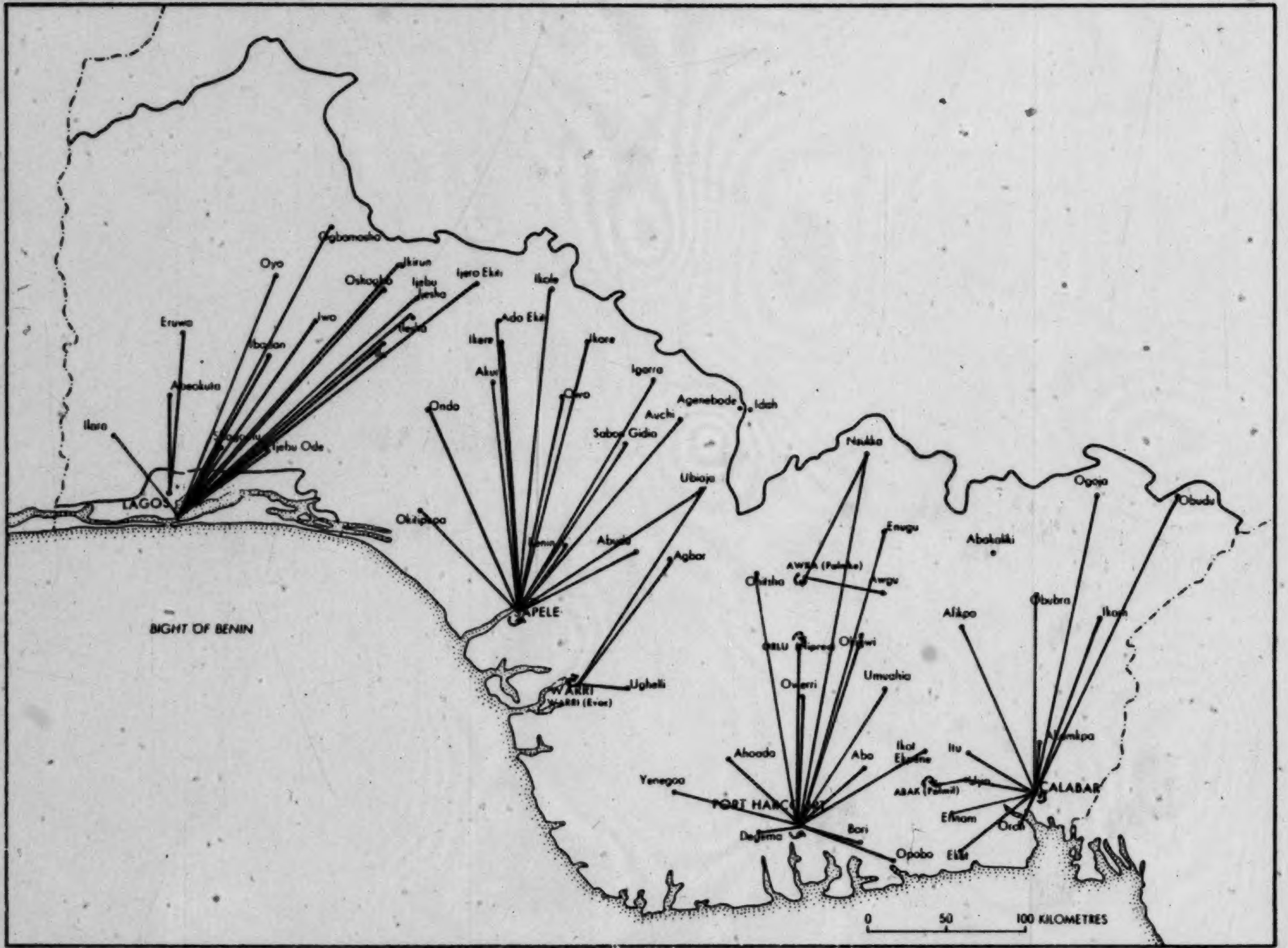

Ilaro
Eruwa
Abeokuta
LAGOS
Oyo
Ogbomosho
Ibadan
Iwo
Oshogbo
Ikirun
Ijebu
Ijesha
Ilesha
Ijero Ekiti
Shagamu
Ijebu Ode
BIGHT OF BENIN
Ondo
Okitipupa
Akure
Ikere
Ado Ekiti
Ikole
Ikare
Owo
Igarra
Agenebode
Idah
Auchi
Sabon Gidia
Ubiaja
Benin
Abudu
Agbor
SAPELE
WARRI
WARRI (Evas)
Ughelli
Nsukka
Enugu
AWKA (Palmke)
Awgu
Onitsha
ORLU
Okigwi
Owerri
Umuahia
Ahoada
Yenegoa
PORT HARCOURT
Degema
Bori
Opobo
Abo
Ikot Ekpene
ABAK (Palmil)
Uyo
Itu
Eket
Eman
Oron
CALABAR
Akamkpa
Afikpo
Abakaliki
Obubra
Ikom
Ogoja
Obudu
0
50
100 KILOMETRES

FIGURE 54 OPTIMAL PATTERN OF PALM KERNEL SHIPMENTS TO FIVE INTERNAL DEMAND POINTS AND ONE MAJOR EXTERNAL DESTINATION OBTAINED FROM COST 2

There are some differences between these patterns, however. In Cost1 Model (Figure 53), Ife Ilesha and Ijero Ekiti shipped through Sapele port to the external destination but in Cost2 Model they shipped through Lagos port. Nsukka shipped through Sapele port in Cost1 Model but in Cost2 Model, it shipped through Port Harcourt port. Awgu and Ikot Ekpene shipped to Port Harcourt port and Calabar port, respectively in Cost1 Model whereas Awgu shipped to Awka (Palmke) and Ikot Ekpene shipped to Calabar port in Cost2 Model.

6.3.6 Optimal Dual Solution of Palm Kernel Shipments to the Internal Demand Points and One Major Destination

Figures 55 and 56 illustrate the respective spatial patterns for the optimal dual solution of the supply points (ui) for the palm kernel shipping problem to the internal destinations and one major external destination obtained from Cost1 and Cost2 Models. These patterns indicate that the greatest savings in shipping bills will be made if palm kernel production were concentrated in the immediate hinterlands of the ports. In both models, the highest value of ui was obtained at Warri port (ui = 1319 in Cost1 Model and ui = 1761 in Cost2 Model). This means that Warri port is the supply point that is best located for increasing the supply of palm kernels. The relative costs of the supply points increase from the south towards the interior where it is less favourable to increase the demand for palm kernels.

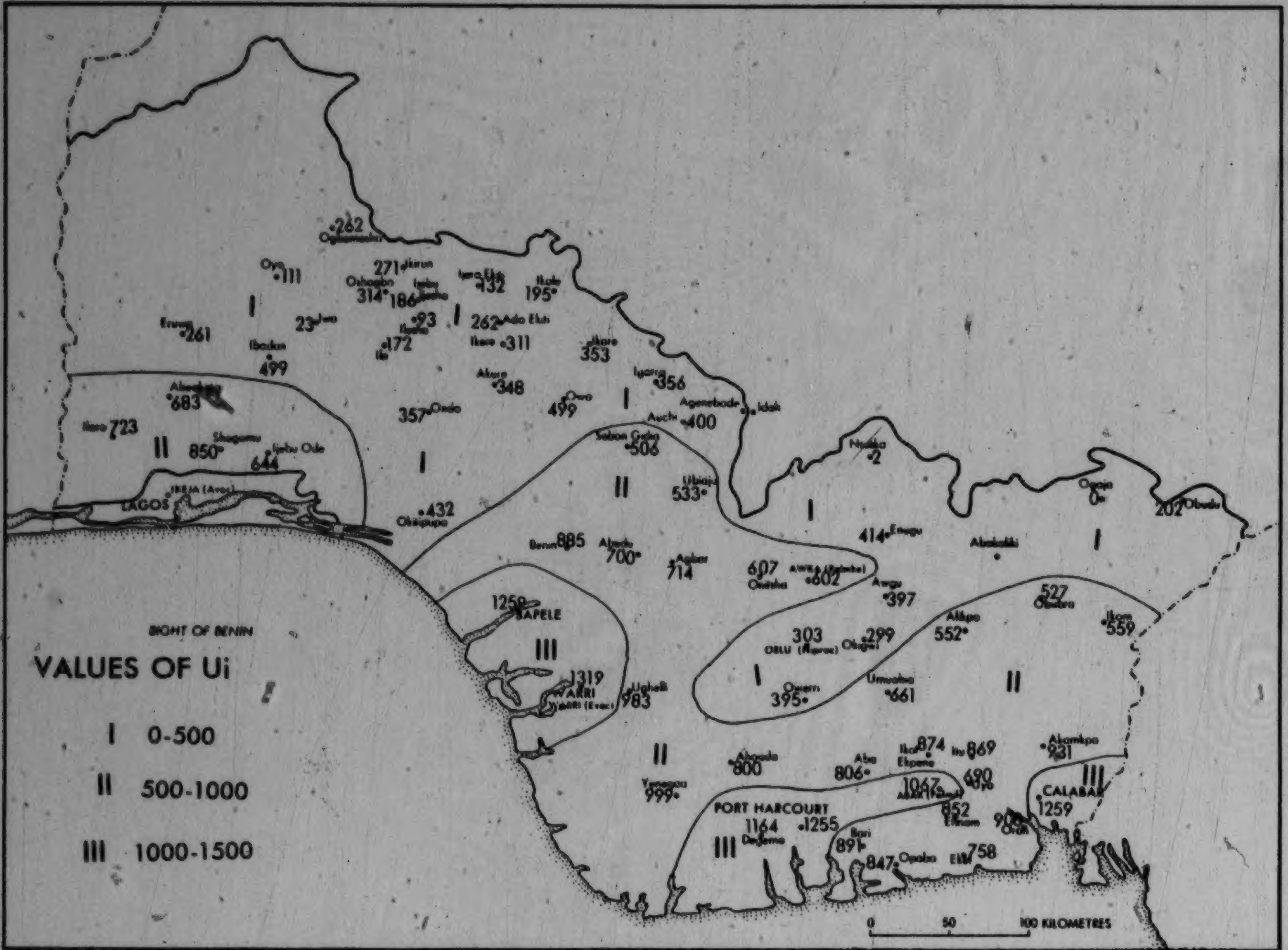

VALUES OF Ui
I 0-500
II 500-1000
III 1000-1500
BIGHT OF BENIN
Ogbomosho 262
Oyo 111
271 Ikirun
Oshogbo 314
186
Iwo 23
Ibadan 499
Eruwa 261
93
Ilesha
Ife 172
Iyara Ekiti 132
Ikole 195
262 Ado Ekiti
Ikere 311
Ikare 353
Akure 348
Owo 499
357 Ondo
Igarra 356
Agenebode
Idah
Auchi 400
Abeokuta 683
Ilaro 723
Shagamu 850
Ijebu Ode 644
IKEJA (Avec)
LAGOS
Okitipupa 432
Sabon Gida 506
Ubiaja 533
Benin 885
Abudu 700
Agbor 714
607 Onitsha
AWKA (Agbaba) 602
Nsukka 2
414 Enugu
Abakaliki
Ogoja 0
202 Obudu
Awgu 397
303 OBLU (Agwac)
Okigwi 299
Owerri 395
Umuahia 661
Afikpo 552
527 Obubra
Ikom 559
SAPELE 1259
1319 WARRI
Effurun (Evac)
Ughelli 983
Yenagoa 999
Ahoada 800
Aba 806
Ikot Ekpene 874
Itu 869
690 Uyo
1067 Abak
852 Eket
Akamkpa 931
CALABAR 1259
908 Oron
PORT HARCOURT
1164 Degema
1255
Bori 891
847 Opobo
Eket 758
0
50
100 KILOMETRES

FIGURE 55 OPTIMAL DUAL SOLUTION OF PALM KERNEL SHIPMENTS TO FIVE INTERNAL DEMAND POINTS AND ONE MAJOR EXTERNAL DESTINATION OBTAINED FROM COST 1.

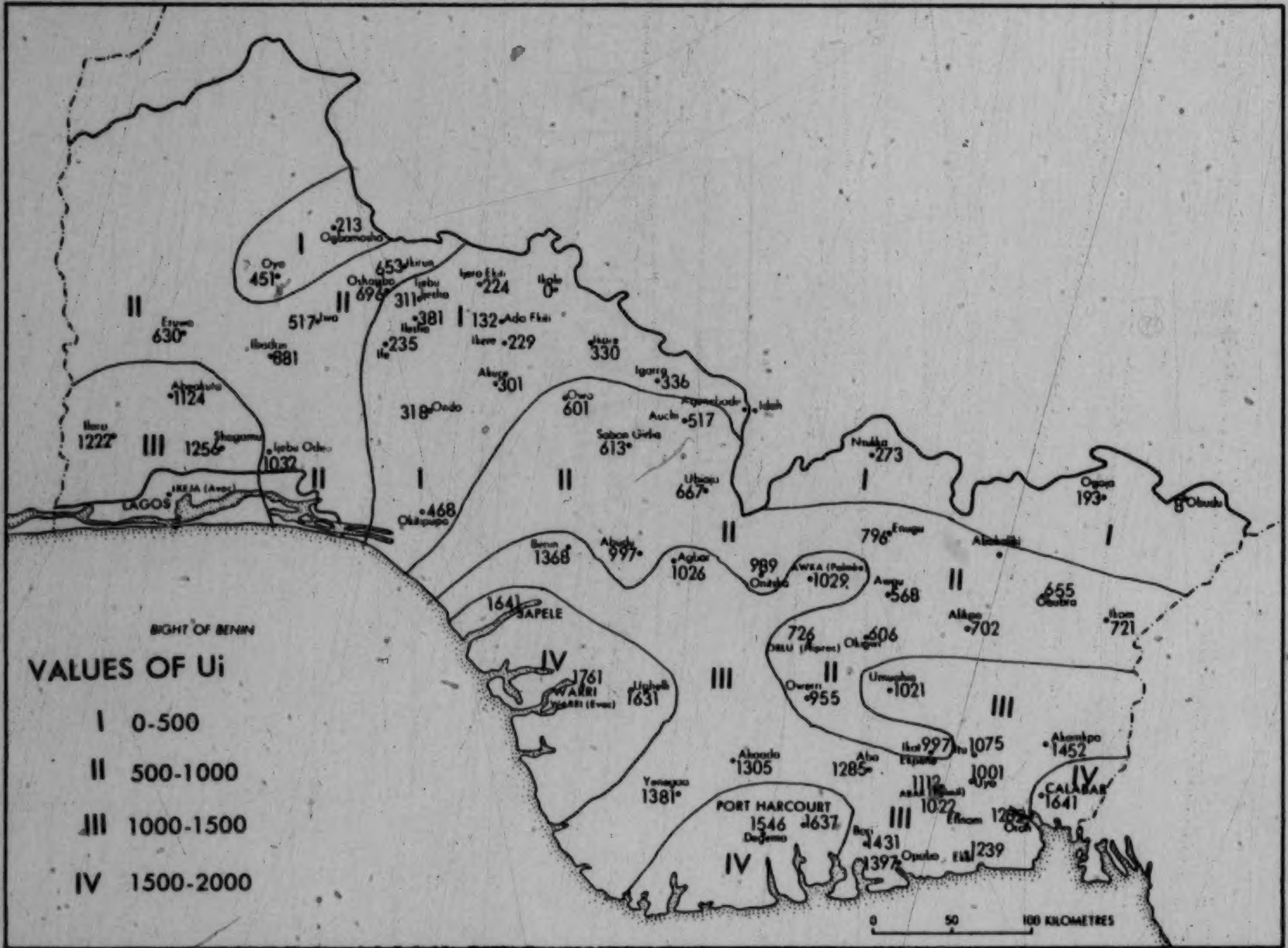

VALUES OF Ui
I 0-500
II 500-1000
III 1000-1500
IV 1500-2000
BIGHT OF BENIN
0 50 100 KILOMETRES
LAGOS
IKEJA (Avec)
Ilaro 1222
Abeokuta 1124
Shagamu 1256
Ijebu Ode 1032
Eruwa 630
Ibadan 881
Oyo 451
Ogbomosho 213
Iwo 517
Oshogbo 696
Ikirun 653
Ijebu Jesha 311
Ilesha 381
Ile 235
Igara Ekiti 224
Ikole 0
Ado Ekiti 132
Ikere 229
Akure 301
Ondo 318
Okitipupa 468
Owo 601
Igarra 336
Auchi 517
Idah
Sabon Gida 613
Ubiaja 667
Benin 1368
Abudu 997
Agbor 1026
Onitsha 989
AWKA (Palmko) 1029
SAPELE 1641
WARRI 1761
Ughelli 1631
Nsukka 273
Ogoja 193
Obudu
Enugu 796
Abakaliki
Awgu 568
Obubra 655
Afikpo 702
Ikom 721
Okigwi 606
ORLU (Pioneer) 726
Owerri 955
Umuahia 1021
Ikot Ekpene 997
Itu 1075
Uyo 1001
Akamkpa 1452
CALABAR 1641
Abak 1112
1022
Eket 1239
Oron 1282
Opobo 1397
Bori 1431
Aba 1285
Ahoada 1305
Yenagoa 1381
PORT HARCOURT 1637
Degema 1546

FIGURE 56 OPTIMAL DUAL SOLUTION OF PALM KERNEL SHIPMENTS TO FIVE INTERNAL DEMAND POINTS AND ONE MAJOR EXTERNAL DESTINATION OBTAINED FROM COST 2.

The optimal dual solution for the demand points (vj) for the palm kernel shipping problem to the internal demand points and one major external destination indicate the relative costs of increasing demand capacity at these demand points (Table 20). Costi Model suggests that the Palm Produce Board would incur higher shipping bills if demand capacity for this commodity were increased at the external destination than if demand were increased in any of the processing mills in the country, especially at Orlu (Niproc), Awka (Palmke) and Abak (Palmil). Among the internal demand points themselves, the model suggests that the Board would incur higher shipping bills if demand capacity for palm kernels were increased at Warri (Evoc) and Ikeja (Von) than if demand were increased at Abak (Palmil), Orlu (Niproc) and Awka (Palmke). For example, to increase demand capacity at Warri (Evoc) relative to Abak, Orlu and Awka, will result in the respective costs of 252, 954 and 558 whereas increasing demand at these processing mills relative to Warri (Evoc) will result in less saving in the shipping bills of the Board.

The Board will however incur lower shipping bills if the demand for Nigerian palm kernels at the external destination were increased relative to the demand at Warri (Evoc) and Ikeja (Von). This suggests that in order to reduce the shipping bill for palm kernels by the Palm Produce Board in the entire system, the demand capacity at Abak, Orlu and Awka but not Warri and Ikeja may be

TABLE 20. THE DEMAND DUAL SOLUTION OF PALM KERNEL SHIPPING PROBLEM TO INTERNAL DEMAND POINTS AND ONE MAJOR EXTERNAL DESTINATION

NAME OF DEMAND POINT	VJ IN COST1	VJ IN COST2
ONE DESTINATION	1450	1832
WARRI (Evoc)	1410	1852
IKEJA (Avoc)	1339	1780
ABAK (Palmil)	1158	1203
AWKA (Palmke)	852	1279
ORLU (Niproc)	456	878

increased.

The same relationships were also obtained from Cost2 Model. Increased demand capacity for palm kernels at Warri (Evoc) and Ikeja (Von) relative to other internal demand points would result in higher shipping bills for the Board. Although Warri and Ikeja are less favourable processing mills for increasing the palm kernel demand capacity than the other processing mills they are more favourably suited for the same purpose with regard to the external destination. In both models, Warri (Evoc) is the least favourable internal demand point for increasing demand capacity and it had the higher ui value then other mills in both models. This is expected since it is better for the Board to increase supply of palm kernels at the demand point where it is most expensive for it to expand demand capacity.

6.3.7 Modal Composition and Linkage Allocation of Palm Kernel Shipments to the Internal Demand Points and One Major Destination

Generally, the models performed in the same way as their respective equivalents in the ealier formulation. Cost1 Model (Figure 57) still makes more shipments by road than Cost2 Model (Figure 58). As in the earlier model, all the supply regions in the Western Railway District and Enugu on the Eastern Railway District shipped respectively to Lagos and Port Harcourt ports by rail. Umuahia and Aba on the Eastern Railway District shipped to Port Harcourt port by road (Figure 57).

In this formulation, Cost2 Model makes greater use of the railway than Cost1 Model. As in the earlier formulation, all the supply regions on the Eastern and Western Railway Districts shipped by rail to Port Harcourt port and Lagos port, respectively. In addition to these, four other supply regions (Ijero Ekiti, Ijebu Ijesha, Ilesha and Ogbomosho) transhiped to the railway at either Ikirun or Oshogbo (Figure 58).

There was not much difference, however, in the percentage of total shipments through Lagos port that were made by rail in both models (55.6 percent in Cost1 and 59.6 percent in Cost2 Model). This can be explained by the fact that it was only small quantities of palm kernels from the four supply regions that were transhipped to the rail in

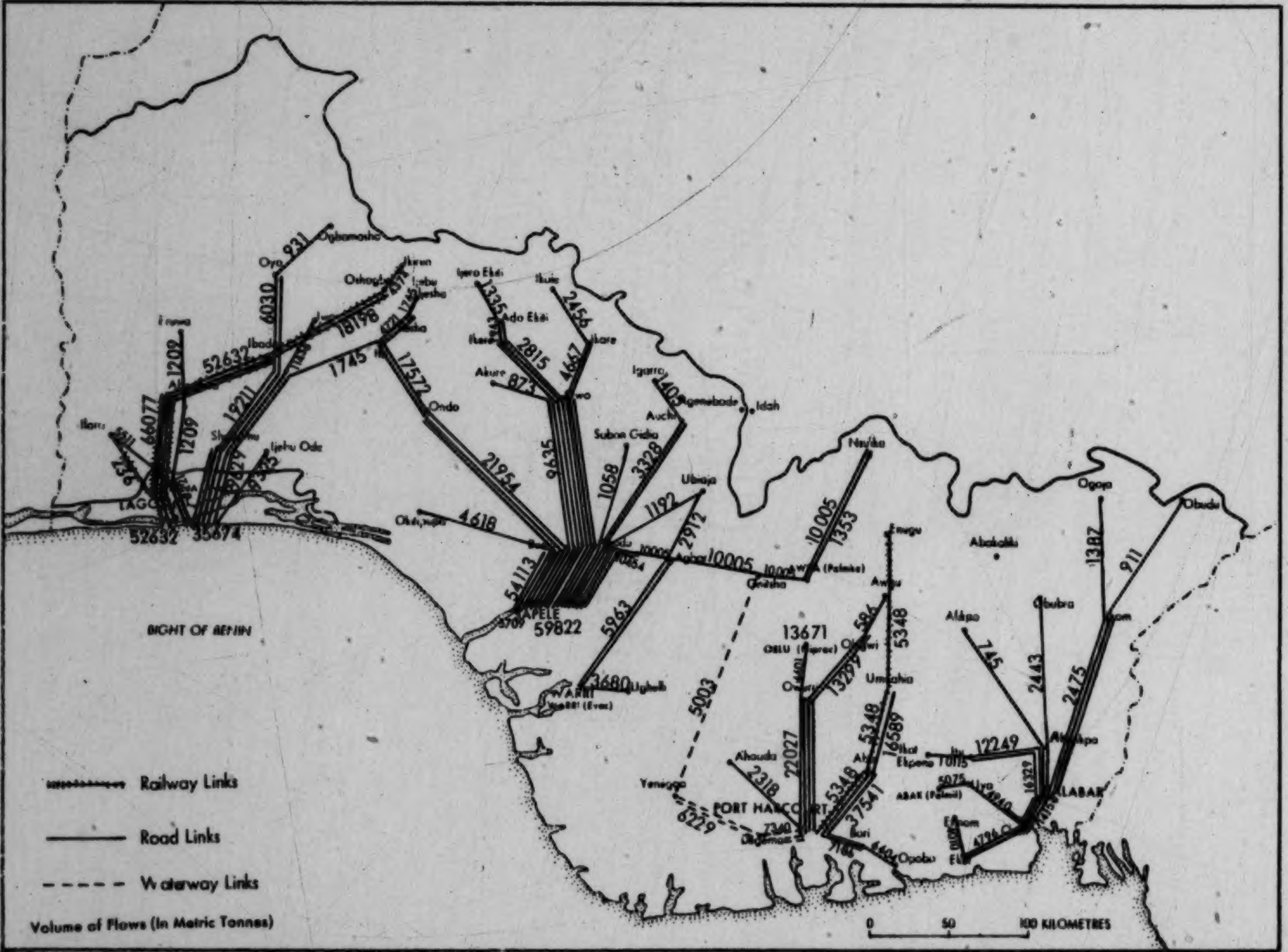

Oyo
931
Ogbomosho
6030
Oshogbo
Ilesha
Ikirun
Iwo
Ibadan
52632
18198
1209
Ilaro
66077
19211
1745
17572
Ondo
Ijebu Ode
Shagamu
LAGOS
52632
35674
Igara Ekiti
1335
Ado Ekiti
Ikere
2815
Ikole
2456
Ikare
4667
Owo
Akure
873
Igarra
1405
Agenebode
Idah
Auchi
Sabon Gida
3328
1058
9635
21954
Okitipupa
4618
1192
Ubiaja
2912
10005
Asaba
Onitsha
Nsukka
1353
AWKA (Palmko)
Enugu
Abakaliki
54113
SAPELE
59822
5963
WARRI
3680
Ughelli
BIGHT OF BENIN
5003
13671
OBLU (Pamol)
Owerri
586
13299
5348
Umuahia
Okigwi
22027
Aba
16589
5348
37541
Ahoada
2318
PORT HARCOURT
Yenagoa
6229
7340
Degema
Bori
7165
440
Opobo
Ikot Ekpene
11015
17249
Itu
ABAK (Palmil)
5075
Uyo
16329
Eket
4796
Eket
Afikpo
745
Obubra
2443
Akamkpa
2475
Ikom
1387
Ogoja
911
Obudu
CALABAR
Abakaliki
0
50
100 KILOMETRES
Railway Links
Road Links
Waterway Links
Volume of Flows (In Metric Tonnes)

FIGURE 57 MODAL COMPOSITION AND LINKAGE ALLOCATIONS OF PALM KERNEL SHIPMENTS TO FIVE INTERNAL DEMAND POINTS AND ONE MAJOR EXTERNAL DESTINATION OBTAINED FROM COST 1

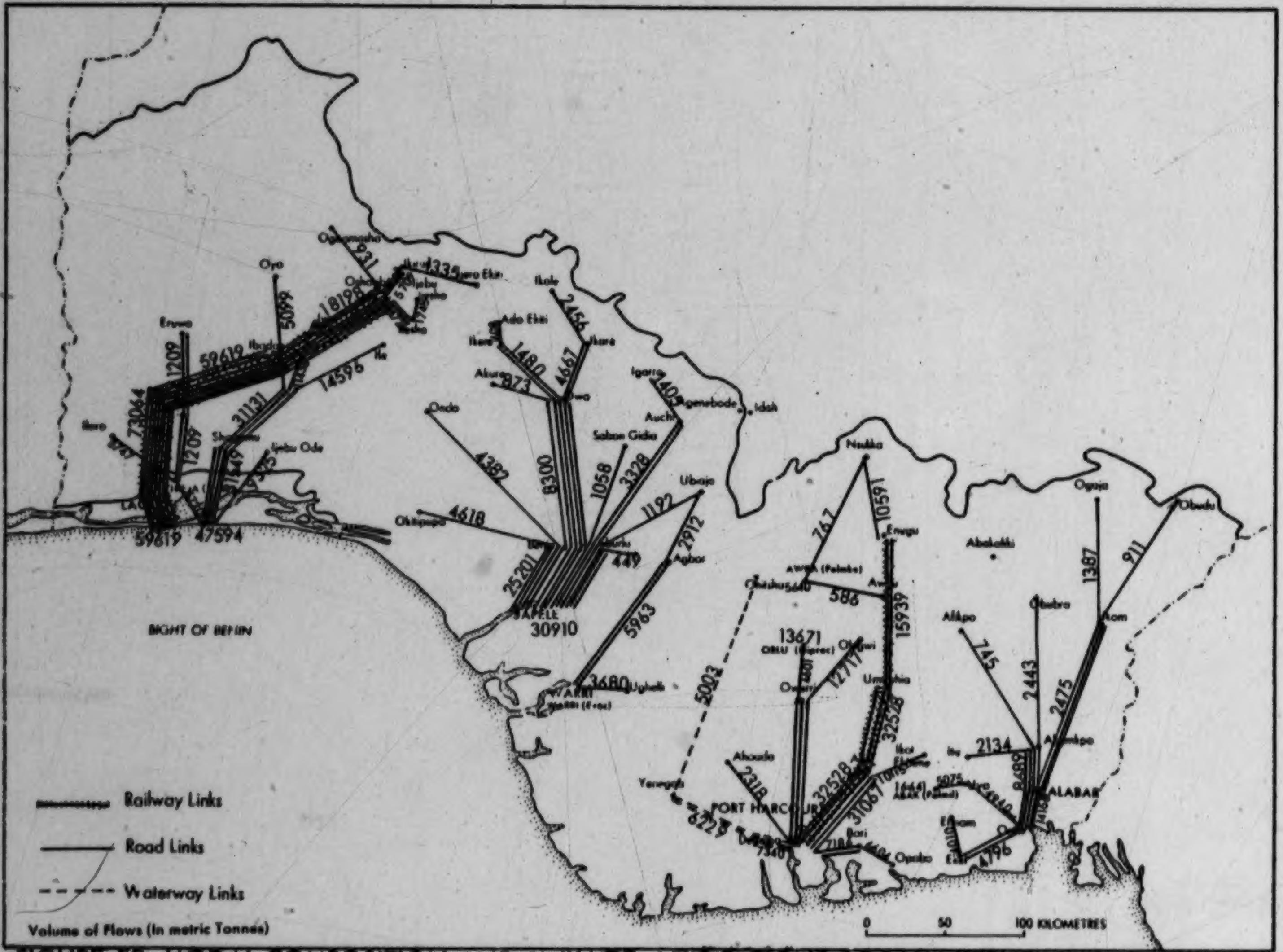

Ogbomosho
931
Oyo
5099
18198
1335
Ijero Ekiti
Ikole
2456
Ado Ekiti
Ikere
1480
Ikare
4667
Akure
973
Owo
Eruwa
1209
59619
Ibadan
14596
Ife
73064
Ilaro
31131
1209
Shagamu
Ijebu Ode
LAGOS
59619
47594
BIGHT OF BENIN
Ondo
4382
8300
Igarra
2405
Agenebode
Idah
Auchi
Sabon Gida
1058
3328
Ubiaja
1192
2912
Agbor
4618
Okitipupa
449
25201
SAPELE
30910
5963
3680
Ughelli
WARRI
WARRI (Exp)
Nsukka
767
10591
Enugu
AWKA (Paleke)
Onitsha
586
15939
13671
ORLU (Ugwu)
Okigwi
12717
Owerri
Umuahia
32528
5003
Ahoada
2318
Ikot Ekpene
32528
31067
Yenagoa
PORT HARCOURT
6229
7340
Bori
7186
Opobo
Abakaliki
Ogoja
1387
911
Obudu
Ikom
Obubra
Afikpo
745
2443
2475
Itu
2134
Akamkpa
1664
ABAK (Paleke)
5075
8689
CALABAR
Eket
1796
Railway Links
Road Links
Waterway Links
Volume of Flows (In metric Tonnes)
0
50
100 KILOMETRES

FIGURE 58 MODAL COMPOSITION AND LINKAGE ALLOCATIONS OF PALM KERNEL SHIPMENTS TO FIVE INTERNAL DEMAND POINTS AND ONE MAJOR EXTERNAL DESTINATION OBTAINED FROM COST 2

Cost2 Model. In both models, there were no transhipments to the waterway and only Onitsha, Yenegoa and Degema located along the River Niger shipped to Port Harcourt port by waterway.

As in the case of cocoa, Cost2 Model encourages the use of railway and waterway more than Cost1 Model. In fact, the Palm Produce Board could have shipped more efficiently by employing the services of the road transport carriers or by employing the licenced buying agents to undertake the shipments and transfering to cheaper rail and waterway modes at the appropriate transhipment centers. It has already been indicated that these findings are contrary to the present pattern of marketing and transporting export commodities in Nigeria. The Commodity Boards continue to employ the services of the licenced buying agents in spite of the higher shipping bills that they incur. These higher bills cannot be justified unless the agents perform important non-economic functions for the Boards.

6.3.8 Discussion of the Relative Changes in the Pattern of Palm Kernel Shipments Through the Ports

The results of the models obtained from shipping palm kernels through the ports to one major external destination indicate that the given demands for palm kernels at the ports are causing higher shipping bills to be incured by the Palm Produce Board. Table 21 summarizes the actual quantities of palm kernels shipped through the ports under

TABLE 21. PERCENTAGE OF PALM KERNEL SHIPMENTS THROUGH THE PORTS

NAME OF PORT	ACTUAL DEMAND		SHIPMENTS TO ONE DESTINATION COST1 DEMAND		COST2 DEMAND	
	Quantity	%Total	Quantity	%Total	Quantity	%Total
LAGOS	107295	39.0	88306	32.6	107213	39.6
P. H. PORT	107775	39.8	86715	32.0	106835	39.4
CALABAR	32559	12.0	36056	13.3	25941	9.6
SAPELE	17698	6.5	59822	22.1	30910	11.4
WARRI	5572	2.1	0	NIL	0	NIL

the different formulations of the model. The highest percentages of palm kernels are demanded at Lagos and Port Harcourt ports. These two ports still have the highest percentage of palm kernel shipments made through them in order to satisfy the demand at the external destination in both models. In these models, Sapele port had a higher percentage of palm kernels shipped through it to the external destination than it actually demanded.

Table 22 shows the relative percentages of palm kernel shipments through the ports when the demand at one external destination was considered. These were obtained by comparing the percentage of shipments through these ports to the external demand point with the actual percentage demand at these ports.

In Cost1 Model, shipments through Lagos and Port Harcourt ports decreased while shipments through Calabar and Sapele ports increased. In Cost2 Model, there was slight

TABLE 22. RELATIVE PERCENTAGE OF PALM KERNEL SHIPMENTS THROUGH THE PORTS TO ONE MAJOR EXTERNAL DESTINATION

NAME OF PORT	RELATIVE PERCENTAGE CHANGES COST1 MODEL	COST2 MODEL
LAGOS	-6.4	+.6
PORT HARCOURT	-7.8	-.4
CALABAR	+1.3	-2.4
SAPELE	+15.6	+4.9
WARRI	NIL	NIL

increase at Lagos port while there was also a very slight decrease at Port Harcourt port. In this model, the demand at Sapele increased by +4.9 percent while the demand at Calabar decreased by -2.4 percent.

There were no shipments through Warri port to the external destination and only a few surrounding supply regions (Ughelli and Ubiaja) shipped to the palm kernel crushing mill at Warri (Evoc). The increase in demand at Sapele port in both models indicates that considerable savings in the shipping bills of the Palm Produce Board will be achieved if the demand capacity for palm kernels is increased at Sapele port. While the demand at Lagos and Port Harcourt ports were reduced in both models, the demand at Calabar port was increased in Cost1 Model but reduced in Cost2 Model. The implications of these findings toward formulating a more efficent transport policy and recommendations for future research resulting from these findings are discussed in the next chapter.

6.4 Summary of the Cocoa and Palm Kernel Shipping Problems

Although the cocoa and palm kernel shipping problems have been dealt with separately, the results obtained from the different problems can be summarized and discussed together. Only the optimal pattern of shipping these commodities are discussed and not the diagrams which would be obtained by overlaying the corresponding individual results of the problems. There may be some relationships between the problems that may help to improve the transportation policies of the Cocoa Board and Palm Produce Board. The implications of the results from the two problems may also indicate possible areas of co-operation between these Boards.

Both problems indicate that apparently sub-optimal shipments which are more expensive to the system were being made because of the nature of the demand for cocoa and palm kernels at the respective demand points. If individual shippers do ship to their least cost ports then they may actually be optimizing. When shipments to one major external destination was considered the optimal shipment pattern obtained is more representative of the shipping pattern for individual shippers.

Table 23 illustrates that the Cocoa Board and the Palm Produce Board would make considerable savings in their shipping bills by reallocating the demand for these commodities at the ports. It also indicates that if these

TABLE 23. SUMMARY OF TOTAL SHIPPING BILLS FOR COCOA AND PALM KERNEL SHIPPING PROBLEMS

A.

	$\sum\sum x_{ij}T_{ij}$ (Cost1) Actual Port Demand	$\sum\sum x_{ij}T_{ij}$ (COST1) Adjusted Port Demand	% of Cost from Adj Demand of Former Cost	Savings in Total Cost
COCOA	N2,256,631	N2,097,932	93%	N158,699
P KERNEL	N2,606,704	N2,464,915	94.6%	N141,789
TOTAL	N4,863,335	N4,562,847	93.8%	N300,488

B.

	$\sum\sum x_{ij}T_{ij}$ (Cost2) Actual Port Demand	$\sum\sum x_{ij}T_{ij}$ (Cost2) Adjusted Port Demand	% of Cost from Adj Demand of Former Cost	Savings in Total Cost
COCOA	N2,408,527	N2,361,820	98.1%	N46,707
P KERNEL	N2,670,503	N2,627,015	94.4%	N43,488
TOTAL	N5,079,030	N4,988,835	98.2%	N90,195

Boards used their road transport differential and also adjusted the demand for the commodities at the ports a total of N90,195 would have been saved on shipping bills. If the Boards employed the road transport freight rates of the transport companies instead of their own road transport differential and also adjusted the demand for the commodities at the ports, an additional N210,293 would have been saved. This would have resulted in a total savings of N300,488 by the two Boards in 1976/77.

The total costs of all the models which employed the road transport freight rates of the transport firms (Cost1 Model) were lower than the total costs of equivalent models which employed the road transport differential of the Commodity Boards (Cost2 Model) for all shipments of cocoa and palm kernels. This indicates that the Boards would save on shipping bills by employing the services of the carriers for shipping the commodities to the demand [illegible]ints instead of paying the licensed buying agents to undertake the shipments.

Table 24 shows that the total shipping bill for both commodities obtained from Cost2 Model is 4.6% higher than that obtained from Cost2 Model when the actual demand at the ports are strictly adhered to while Cost2 Model is as much as 9.6% higher that Cost1 Model when the demands at the ports are adjusted. This means the the Boards would have saved N215,695 by employing the carriers to ship according to the demand at the ports, while these Boards would have

TABLE 24. RELATIVE DIFFERENCES BETWEEN COST1 AND COST2 MODELS FOR COCOA AND PALM KERNEL SHIPPING PROBLEMS

	ACTUAL PORT DEMAND		ADJUSTED PORT DEMAND	
	COST2-COST1	% DIFF OF COST1	COST2-COST1	% DIFF OF COST1
COCOA	N151,896	+6.7%	N263,888	+12.6%
PALM KERNELS	N63,799	+2.5%	N162,100	+6.6%
TOTAL	N215,695	+4.6%	N425,988	+9.6%

saved N425,988 by allowing the carriers to ship from the supply points directly to the external demand points.

In all cases, Cost2 Model makes greater use of the cheaper railway and waterway modes than Cost1 Model which makes more use of shipments by road. It was observed that there are numerous transport companies that provide regular services from Lagos and other seaports to all parts of the country. Due to the strong attraction for return loads from the ports, the long-haul shipments to these ports by the carriers cost much less that the Commodity Board rates which is based directly on distance or mileage data. The road transport differential of the Boards is so expensive that shipments that began by road in Cost2 model can only reduce costs by transhipping to the cheaper railway and waterway modes.

Apart from adjusting the port demands, these Boards would be shipping more efficiently if they employed the services of the carriers instead of paying the licenced buying agents to undertake these shipments or if they still employed the services of the agents and also transhipped to the cheaper railway or waterway modes.

These findings are contrary to the present pattern of marketing and transporting export commodities in Nigeria. The Commodity Boards still employ the licenced buying agents to transport these commodities and these agents are paid the road transport differential of the Boards irrespective of the mode actually employed. It is possible that these agents could negotiate the cheaper rates from the carriers and still claim the higher road transport differential from the Board. Thus, the Boards continue to incur higher shipping bills by employing the services of these agents. These higher bills cannot be justified unless there are other important non-economic functions which the agents perform for the Boards.

7. Chapter Seven CONCLUSIONS AND RECOMMENDATIONS

7.1 Summary

This study has investigated the optimal pattern for shipping cocoa and palm kernels in Nigeria from the points where they are are purchased to the various demand points, in 1976/77. The shortest paths obtained from modelling the transportation network as a Transhipment Problem was employed, as if they were direct links, in the Transportation Problem in order to obtain the optimal pattern of shipment. The shortest paths that appeared in the optimal solution were then re-interpreted link-by-link in order to illustrate the actual routes over which shipments were made in the optimal model. Thus, the study has added another practical example to the empirical literature on the Transportation Problem in which there are two or more modes of transportation for more than one commodity.

7.2 Problems and Misgivings About the Model

7.2.1 Problems Caused by Isolated Analysis

Partial models are not ways of generating well-defined and rigorously justifiable solutions to overall transportation planning problems. Because of our ignorance regarding many other relationships involved and the important implications of these decisions, such models are best regarded as heuristic frameworks within which to generate in rough outline, some inputs into the general planning programs. The ultimate evaluation, specification and adoption of these programs will have to be based on more detailed analysis which will capture the multivariate nature of the regional transportation system operations and impacts and/or the subjective qualitative judgements made by experienced planners and policy makers. In fact, these partial models are best regarded as inputs to the decision making process rather than the decision making process itself. They are useful not only for directly indicating what type of other planning programs should be undertaken, but also in clarifying objectives and identifying additional research.

The model employed in this study undertakes a partial analysis of the factors involved. The results obtained from the model are based on the optimal pattern that would be obtained if the shipping bill of the Commodity Boards were the only factor to be taken into consideration. There are many other important factors that may greatly influence where most agricultural commodities can be grown apart from the shipping bill. These include such factors as soil conditions, climate, inertia and tradition. This means that even if the demand dual solutions (ui) suggest expanding cocoa and palm kernel supply from certain regions these may not be feasible due to other factors.

Barr & Smillie (1972) suggested that in problems where the spatial configuration of flow patterns is important, the alternative optimal solutions and good sub-optimal solutions should also be investigated. Four such alternative optimal solutions were obtained for the palm kernel shipping problem to the internal demand points and the ports. It is possible that each of these solutions reflects a different aspect of the economic environment which was not considered explicitly by the model.

7.2.2 Problems Resulting From Assumptions of the Model

The model did not take capacity into consideration. Link capacity could be incorporated by allowing the shipping bill to vary according to the quantity of the commodity shipped. This would have resulted in a non-linear or piece-wise linear Transportation Problem which would require a more complex solution. Link capacities could also have been taken into consideration by placing an absolute limit on the quantity of the commodities that should be shipped along each link but data on these were not available.

It had already been indicated that the model would demand data on the capacity of the links as well as data on the total quantity of other commodities, excluding cocoa and palm kernels, shipped along each link in order to take capacity into consideration in this way. Thus, the problem is not simply a question of availability of data but the problem of working on a sub-system within a bigger system. Since link capacities were not taken into consideration, it was not possible to identify the saturated linkages which constitute bottlenecks to efficient utilization of the transportation network.

The port capacities for the commodities were not also considered. It is therefore unclear whether the ports could actually handle the quantities of these commodities suggested for them in the optimal models. The results can only give impressions of where demand capacities may be expanded without any indication as to whether the capacity of the ports can handle these new demands. Despite these problems and misgivings, some interesting results have been obtained.

7.3 Summary of Results

7.3.1 Results From Export Commodity Shipments

The cocoa and palm kernel shipping problems indicate that Lagos and Port Harcourt ports demand the greatest quantities of these commodities and that the highest quantities of the commodities are also shipped through them to the external destination. The models obtained from the adjusted port demand suggest that demand capacity be reduced both at Lagos and Port Harcourt ports and that demand capacity be increased at Sapele port. Therefore, the Cocoa Board and the Palm Produce Board may reduce their shipping bills by directing more shipments of these commodities intended for export to Sapele port and diverting some of these shipments from Lagos and Port Harcourt ports. The models from the adjusted port demands also suggest that the demand capacity for cocoa at Calabar port be increased, and the Cocoa Board may benefit from taking this into consideration.

Lagos and Port Harcourt are the two major ports in the country and both have adequate berthing facilities for the large ocean-going vessels that undertake the shipping of Nigerian cocoa and palm kernels to European and North American markets. These ports also handle import traffic and are often congested. Although the models obtained from the adjusted port demand suggest increasing the demand at Sapele port in order to relieve Lagos and Port Harcourt, it is difficult to demonstrate that Sapele port has enough capacity to accomodate this increased demand since port capacities were not taken into consideration. It is possible that the availablity of the ocean-going vessels at Lagos and Port Harcourt actually determines the demand at the ports in which case the implementation of the adjusted port demands suggested by the models may not be feasible. It is therefore suggested that capacity increase at the ports may have to be combined with regulating the shipping vessels to comply with the expansion programme in order to achieve the desired results.

Whereas Cost1 Model of adjusted port demand suggest increasing demand capacity for palm kernels at Calabar port(+1.3%), Cost2 Model suggests that the demand capacity at this same port be reduced(-2.4%). These results are inconclusive with regard to changing the demand capacity for palm kernels at Calabar port. Further investigation is needed in order to ascertain whether other factors which influence the demand for palm kernels at Calabar port should be taken into consideration.

7.3.2 Results from Shipments to Internal Demand Points

Increased processing of these commodities at the internal demand points or the processing mills would also reduce the shipping bills of these Boards. Increased processing of cocoa at Ikeja relative to increasing demand at the external destination would reduce the shipping bill of the Cocoa Board. Similarly, increased processing of palm kernels at Abak (Palmil), Orlu (Niproc) and Awka (Palmke) would cost less than increasing demand capacity at Ikeja (Von) and Warri (Evoc). On the whole, increased processing of palm kernels at Abak (Palmil), Orlu (Niproc) and Awka (Palmke) but not at Ikeja (Von) and Warri (Evoc) relative to the external destination will reduce the shipping bill of the Palm Produce Board. Therefore, the Palm Produce Board may direct more of the palm kernels being shipped to Ikeja and Warri to the external destination or foreign markets while internal processing of palm kernels at Abak, Orlu and Awka may also be expanded in order to reduce shipping bills.

7.3.3 Data Problems and Methods of Improving Data Collection

The sources of data employed in this analysis and modifications of these data were discussed in Chapter Five. Although they are adequate for the purposes of this study, there are problems caused by insufficient data. Data on actual patterns of shipments were not available. It was therefore impossible to compare the optimal pattern with the actual pattern. Such comparison would have revealed where inefficiencies in the shipping patterns are more predominant.

The commodities considered namely, cocoa and palm kernels, are grown in the southern part of the country because data on commodities grown in other parts of the country were not available. This means that the results obtained are applicable only to the southern part and not the whole country. Although concentrating on these two commodities provides some insight into the basic issues involved, a more comprehensive study involving other commodities that are grown in other parts of the country, should be undertaken if data on these become available in future.

Since the actual data on transportation costs on all the links were not available, regression analysis was employed in obtaining a representative model that was used for estimating costs on the links for which actual data were not obtained. Regression analysis gives an indication of overall fit and may not predict costs exactly. This may have caused some estimation problems resulting in the underprediction or overprediction of costs along some links.

The data problems experienced in this study emphasizes the need for building up an adequate data base for development planning in Nigeria. Planning in most developing countries have often been described as planning without facts because of the paucity of data on the vital aspects of the physical, social and economic characteristics of these countries. It is in the interest of the Commodity Boards and the Nigerian economy in general if an efficient data collection policy is adopted. In fact, it is advisable for the Nigerian government to spend money in generating data for research which will help to evaluate the returns from alternative investments in transportation.

The present paucity of data for detailed planning purposes in Nigeria is due to many reasons. Most of the available data on the country's resources are widely dispersed in several files in the government departments and ministries throughout the country. Most of these data have not been collated, synthesized and presented in the form in which they can be used for detailed planning purposes. The length of some of the records is so short and the number of data points so few and scattered all over the country that they are not suitable for analytical and predictive modelling of spatial or temporal patterns of the variables concerned.

The Federal Office of Statistics was established in order to develop data bank and information systems for the easy collation and retrival of data on various aspects of the country's physical, social and economic resources. Unfortunately, this Office hardly publishes up-to-date data and in most cases the published statistics are often inadequate in spatial details because they are provided only at the state levels. This explains why it was not possible to obtain data on the quantities of the export commodities purchased in the provinces from this source.

The existing system of generating statistical data and the simple direct gathering of factual data on relevant variables is not comprehensive. Some of the data on traffic flows which presently exist were the result of widely scattered and often unco-ordinated 'ad hoc' projects many of which were carried out on the spur of the moment to meet certain immediate needs. This explains why data on the capacity of the routes were not available. A more comprehensive approach to data collection is preferable to the present approach in order to plan adequately for the future development of transportation in the economy of Nigeria. This requires a large scale traffic plan at the national level and the coverage of the whole country on a systematic basis instead of the present sporadic approach to traffic counts. Nigeria is still struggling to evolve a comprehensive Origin-Destination survey of passenger and goods movement. Attempts should also be made to develop facilities for the detailed measurement of the essential properties of other relevant transportation variables for planning purposes.

Studies of interregional commodity and traffic flows will become more important in the future because with more economic development there will be more regional specialization and the desire to reduce distribution costs will be much stronger. The Commodity Boards should therefore generate more data to enable more quantitative studies of this nature and other detailed studies for obtaining more rational evacuation policies to be undertaken. It is expected that the establishment of the Commodity Board system (to replace the former State Marketing Board system) will help to provide good and up-to-date marketing information system which will enable more research and improvements in export commodity marketing in Nigeria to be undertaken.

7.4 Summary of Recommendations

1. It has been demonstrated that there are obvious savings in shipping costs to be made by the Cocoa Board and the Palm Produce Board from adjusting both the sources of supply and the pattern of demand for these commodities. The spatial pattern of the dual variables (ui) suggest adjusting the supplies (Si) in order to save shipping costs. The pattern of Si's depend on so many other factors that some of the adjustments suggested by the models (for example, increasing supplies at the ports) may in fact, not be feasible. The demand dual variables (vj) also suggested that the demand for these commodities at the port (Dj) should be adjusted since

the existing pattern of demand result in higher shipping bill for the Boards. Since the capacities of the ports were not taken into consideration, it may not be feasible for these ports to handle the adjusted port demands. These results may however, be employed as guidelines for shifts in expanding production or changing demand capacities at the ports in future.

2. In all cases, the road transport freight rate of the carriers (Cost1 Model) result in lower total shipping bills than the road transport differential of the Boards (Cost2 Model) which makes greater use of cheaper railway and waterway modes. This suggests that the Boards would reduce their shipping bills by employing the carriers instead of the licenced buying agents to undertake these shipments. The Boards may also reduce shipping bills by employing the agents and transhipping to the cheaper railway and waterway modes at the transhipment centers. Apart from increasing the overhead costs of the Boards, there are other problems involved in taking either approach. These problems are caused by the unique role of the licenced buying agents in the marketing system for export commodities in Nigeria.

In addition to transporting these commodities, the licensed buying agents often have to undertake 'bush collection' in order to purchase commodities from the producers who are unable to take their products to the grading stations. Although this stage is not considered in this study, it is a very important stage in the marketing system of export commodities in Nigeria because it makes it possible to evacuate produce that would otherwise have been wasted.

The collection by these agents is already well organized. If the Boards employ the services of the carriers instead of the licenced buying agents, these agents may no longer be willing to undertake the 'bush collection' stage. The allowance which the agents get from the Boards for undertaking 'bush collection' acts as incentive to them to buy more produce and thereby make more profit by transporting their purchases. Since the Boards cannot undertake the 'bush collection' without incurring more overhead costs, they are compelled to continue employing the services of the agents instead of the carriers for transporting the commodities to the demand points.

3. The results obtained have some serious implications for modal co-ordination in Nigeria. The Board rates (Cost2 Model) are compatible with transhipment to other transport modes while the transport rates by the carrier (Cost1 Model) are not. This suggestion may be very difficult to implement. The licenced buying agents have their own lorries in most cases and would resent being ordered to ship their purchases by rail since their profits would be considerably reduced. Moreover, the licenced buying agent who delivers his purchases of

produce at Lagos or Port Harcourt port by road is more promptly paid than another agent that shipped by rail.

The quality of services offered by the various transportation modes also creates further problems. Although the cost of moving freight by road is higher than moving it by rail or waterway, the difference may be offset by better service. For example, the lorry picks up the commodity at the producer's farm and eliminates transhipment from lorry to railway wagon or river barges. Moreover, the lorries provide essential supplementary service if perhaps, rail services are interrrupted by washouts, or there is an exceptional large bumper crop. In order to handle increased quantity of produce the railways must have to add to its inventory increased number of locomotive and wagons. The quality of railway services must also have to be improved if the railway is to effectively meet the competition form road transport.

7.4.1 General Conclusion

The model obtained from the road transport differential of the Commodity Boards (Cost2 Model) encourages more efficent utilization of the transportation network by transhipping to the cheaper railway and waterway modes. This model is however more costly than the model obtained from employing the road transport rates of the transport firms (Cost1 Model) which ships mostly by road and so is making inefficient use of the transport network. This creates a problem with regard to choosing which aspect of efficiency in the system the Commodity Boards should be emphasizing. The role of the Boards in helping to promote economic development in the country demands that they be employed as a leverage for transport co-ordination. This suggests that the Boards should continue to employ the licenced buying agents to undertake the shipments and also make them to tranship to the cheaper railway and waterway modes at the transhipment centres. Apart from the problems of implementing this approach already mentioned, it implies more costly pattern of shipments than employing the transport freight rates of carriers (Cost1 Model) which makes inefficient use of the transportation network.

It is rather difficult to decide whether the Commodity Boards should be emphasizing making efficient utilization of the transport network or saving shipping costs. The present study is mainly concerned with the shipping bills of the Boards which may not necessarily involve the efficient utilization of the network and other moral justifications preteining to which of these goals is more benefitial to the country's economy. The model employed in the analysis does not take such equity problems into consideration since the moral factors involved may give rise to ambigous unimplementable policies. In fact, although the normative approach taken in this study may not give comprehensive results, it clearly demonstrates what the results will be in monetary terms, if certain lines of action are taken. These results are very useful in planning for the future.

7.4.2 Suggestions for Further Studies

Although there are a number of further studies related to this this dissertation that could be undertaken, the following areas of research are suggested.

1. The linear cost function (which specifies that shipping cost per tonne of commodity is constant with respect to the tonnage shipped) was assumed in this study because it is consistent with the requirements of a linear programming formulation. Other alternative cost funtions, such as zone rates or decreasing rates over longer distances, may be investgated.
2. The decision variable in the model was the shipping bill of the Commodity Boards. This critical unit of shipping bill consist of the fixed freight rates for the railway and waterway modes, and the road freight rates. The road freight rates are negotiable but are supplied exogenously to the model. Therefore, a sensitivity analysis could be carried out in this direction. Such an analysis would investigate the shipping patterns that would result from changes in the road freight rates and the implication of such changes.
3. This study has demonstrated an application of linear programming model that involves more than one mode of transport and more than one commodity. Other commodities for example, beniseed, coffee and cotton, could be

studied in order to find out whether similar results would be obtained. Also, if data on actual shipments become available in the future, it would be interesting to compare these with the optimal shipments in order to identify inefficiencies in the patterns.

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APPENDIX I

SAMPLE OBTAINED FROM BENIN AS LOADING POINT

NO.	NAME OF TOWN	Dij(Km)	Cij(N)
1.	ABA	307.	5.02
2.	ABAK	401.	6.24
3.	ABAKALIKI	338.	5.39
4.	ABEOKUTA	317.	5.18
5.	ABUDU	54.	4.50
6.	AFIKPO	332.	5.35
7.	AGBOR	69.	3.41
8.	AKURE	171.	3.89
9.	AUCHI	134.	6.80
10.	ASABA	140.	3.74
11.	AWGU	253.	4.27
12	CALABAR	493.	6.70
13.	EKET	409.	6.30
14.	ENUGU	257.	4.15
15.	ETINAM	395.	6.82
16.	FUNTUA	935.	15.90
17.	GBOKO	510.	7.03
18.	GOMBE	1048.	18.10
19.	GUSAU	1048.	18.35
20.	IBADAN	303.	4.98
21.	IFE	229.	3.46
22.	IJEBU ODE	233.	3.78
23.	IKOM	444.	6.58
24.	IKOT EKPENE	377.	6.01
25.	ILESHA	254.	4.03
26.	ILORIN	401.	6.08
27.	ITU	415.	6.14
28.	JOS	760.	13.25
29.	KADUNA	788.	13.80
30.	KANO	1051.	18.69
31.	KATSINA	1255.	22.60
32.	LAGOS	333.	5.00
33.	MAIDUGURI	1355.	21.82
34.	MINNA	608.	11.97
35.	NSUKKA	295.	4.50
36.	OBUBRA	378.	5.86
37.	OKITIPUPA	142.	7.00
38.	ONDO	167.	7.50
39.	ONITSHA	150.	4.00
40.	ORLU	201.	3.90
41.	ORON	426.	4.15
42.	OSHOGBO	286.	4.42
43.	OTURKPO	406.	6.10
44.	OWERRI	243.	4.18
45.	OWO	120.	6.40
46.	PORT HARCOURT	356.	6.20
47.	SABONGIDA ORA	118.	6.50
48.	SAPELE	52.	4.60

49.	SHAGAMU	266.	4.96
50.	SOKOTO	1022.	18.50
51.	UBIAJA	109.	6.20
52.	UMUAHIA	280.	4.18
53.	UYO	377.	6.06
54.	WARRI	101.	2.95
55.	YOLA	1109.	14.57
56.	ZARIA	872.	15.19

SAMPLE OBTAINED WITH CALABAR AS LOADING POINT

NO.	NAME OF TOWN	Dij(Km)	Cij(N)
1.	ABA	143.	6.15
2.	ABAK	87.	5.89
3.	ABAKALIKI	278.	14.75
4.	ABEOKUTA	767.	30.59
5.	AFIKPO	125.	5.99
6.	AGBOR	381.	16.87
7.	AKAMKPA	40.	4.20
8.	AKURE	621.	23.45
9.	AROCHUKWU	96.	6.21
10.	ASABA	312.	12.82
11.	AWGU	217.	11.49
12.	BENIN	493.	18.26
13.	EKET	62.	2.92
14.	ENUGU	278.	14.70
15.	ETINAM	78.	4.29
16.	FUNTUA	1178.	49.95
17.	GBOKO	515.	24.07
18.	GOMBE	1155.	46.29
19.	GUSAU	1090.	53.84
20.	IBADAN	796.	29.48
21.	IDAH	402.	20.09
22.	IFE	679.	24.33
23.	IJEBU ODE	684.	25.65
24.	IKOM	152.	9.30
25.	IKOT EKPENE	108.	4.76
26.	ILESHA	706.	25.27
27.	ILORIN	851.	31.25
28.	ITU	69.	4.32
29.	JOS	872.	37.55
30.	KADUNA	1036.	43.39
31.	KANO	1289.	48.66
32.	KATSINA	1467.	56.04
33.	LAGOS	784.	29.37
34.	MAIDUGURI	1467.	59.26
35.	MINNA	861.	40.29
36.	NSUKKA	320.	17.48
37.	OBUBRA	160.	3.65
38.	OBUDU	319.	4.72
39.	OGOJA	289.	4.83
40.	ONITSHA	301.	12.16
41.	OPOBO	104.	4.91
42.	ORLU	238.	9.56
43.	ORON	24.	4.50
44.	OSHOGBO	737.	27.81
45.	OTURKPO	405.	28.57
46.	OWERRI	201.	8.09
47.	OWO	571.	23.35
48.	PORT HARCOURT	198.	8.47
49.	SAPELE	463.	19.23
50.	SHAGAMU	716.	27.44

51.	SOKOTO	1153.	57.32
52.	UMUAHIA	153.	7.18
53.	UYO	68.	2.60
54.	WARRI	491.	21.54
55.	YOLA	1134.	45.73
56.	ZARIA	1120.	40.82
57.	ETINAM TO UYO	16.	3.70
58.	ORON TO EKET	45.	4.40
59.	ORON TO UYO	52.	4.60

SAMPLE OBTAINED WITH ENUGU AS LOADING POINT

NO.	NAME OF TOWN	Dij(Km)	Cij(N)
1.	ABA	193.	8.72
2.	ABAK	255.	6.03
3.	ABAKALIKI	81.	5.50
4.	ABEOKUTA	547.	20.61
5.	AFIKPO	147.	7.00
6.	AGBOR	188.	8.75
7.	AKURE	428.	16.27
8.	ASABA	118.	6.13
9.	AWGU	61.	4.29
10.	BENIN	257.	10.35
11.	CALABAR	278.	7.84
12.	EKET	257.	12.69
13.	ETINAM	235.	10.12
14.	FUNTUA	916.	28.26
15.	GOMBE	893.	29.07
16.	GUSAU	1029.	34.68
17.	IBADAN	1560.	20.43
18.	IDAH	118.	6.58
19.	IFE	486.	17.63
20.	IJEBU ODE	491.	17.25
21.	IKOM	190.	3.29
22.	IKOT EKPENE	187.	9.51
23.	ILESHA	512.	18.02
24.	ILORIN	658.	22.36
25.	ITU	219.	10.04
26.	JOS	610.	20.56
27.	KADUNA	774.	27.23
28.	KANO	1036.	35.57
29.	KATSINA	1205.	36.44
30.	LAGOS	591.	21.26
31.	MAIDUGURI	1204.	35.75
32.	MINNA	599.	23.67
33.	NSUKKA	58.	3.02
34.	OBUBRA	124.	2.68
35.	OBUDU	251.	6.47
36.	OGOJA	201.	4.89
37.	ONITSHA	108.	6.11
38.	OPOBO	299.	10.43
39.	ORLU	125.	8.63
40.	ORON	264.	3.48
41.	OSHOGBO	544.	19.27
42.	OTURKPO	169.	8.09
43.	OWERRI	148.	8.51
44.	OWO	378.	15.28
45.	PORT HARCOURT	251.	10.22
46.	SAPELE	272.	12.60
47.	SHAGAMU	523.	16.94
48.	SOKOTO	1274.	40.08
49.	UMUAHIA	135.	6.29
50.	UYO	219.	10.76

51.	WARRI	304.	11.59
52.	YOLA	871.	28.72
53.	ZARIA	858.	27.66
54.	AGBOR TO ONITSHA	70.	5.00
55.	UGHELLI TO ONITSHA	164.	7.50
56.	AHOADA TO P. H.	61.	4.80
57.	OWERRI TO ONITSHA	79.	5.00
58.	ORLU TO ONITSHA	55.	4.90
59.	AWKA TO ONITSHA	37.	4.00
60.	IDAH TO NSUKKA	78.	5.40
61.	AWKA TO NSUKKA	108.	6.00
62.	ENUGU TO NSUKKA	58.	4.00
63.	ENUGU TO AWKA	71.	5.00
64.	AWGU TO ENUGU	42.	4.70
65.	AWKA TO AWGU	66.	5.00
66.	AWKA TO OKIGWI	72.	5.50
67.	AWKA TO ORLU	52.	4.80
68.	ORLU TO OWERRI	38.	4.30
69.	OWERRI TO UMUAHIA	62.	4.70
70.	OWERRI TO ABA	61.	4.80
71.	OWERRI TO P. H.	113.	5.20
72.	ABA TO P. H.	64.	4.50
73.	ABA TO UMUAHIA	55.	4.70

SAMPLE OBTAINED WITH IBADAN AS LOADING POINT

NO.	NAME OF TOWN	Dij(Km)	Cij(N)
1.	ABA	610.	23.78
2.	ABAK	672.	26.53
3.	ABAKALIKI	640.	24.63
4.	ABEOKUTA	77.	5.00
5.	AFIKPO	634.	26.59
6.	AGBOR	372.	15.91
7.	AKURE	206.	12.54
8.	ASABA	443.	28.06
9.	AWGU	555.	23.87
10.	BENIN	303.	13.76
11.	CALABAR	520.	27.00
12.	EKET	717.	29.61
13.	ENUGU	560.	22.08
14.	ERUWA	53.	5.00
15.	ETINAM	690.	27.11
16.	FUNTUA	993.	34.27
17.	GOMBE	1226.	37.43
18.	GUSAU	843.	31.62
19.	IDAH	515.	28.04
20.	IFE	89.	5.50
21.	IJEBU ODE	69.	5.20
22.	IKOM	724.	31.26
23.	IKOT EKPENE	679.	25.37
24.	ILESHA	122.	8.41
25.	ILORIN	159.	12.19
26.	IWO	42.	4.40
27.	JOS	938.	30.27
28.	KADUNA	758.	30.81
29.	KANO	1007.	30.22
30.	KATSINA	1068.	39.18
31.	LAGOS	143.	12.20
32.	MINNA	590.	24.73
33.	NSUKKA	607.	25.01
34.	OBUBRA	658.	30.69
35.	OBUDU	858.	30.24
36.	OGOJA	808.	27.45
37.	ONITSHA	452.	20.17
38.	OPOBO	761.	28.36
39.	ORLU	540.	23.41
40.	ORON	729.	27.93
41.	OSHOGBO	113.	8.38
42.	OTURKPO	827.	28.16
43.	OWERRI	555.	23.57
44.	OWO	258.	13.74
45.	OYO	53.	4.50
46.	PORT HARCOURT	658.	26.35
47.	SAPELE	354.	19.40
48.	SHAGAMU	76.	5.30
49.	SOKOTO	892.	34.39
50.	UMUAHIA	582.	26.14

51.	UYO	697.	26.19
52.	WARRI	404.	16.23
53.	ZARIA	829.	30.06
54.	IFE TO IWO	52.	4.50
55.	IFE TO OGBOMOSHO	92.	5.70
56.	IFE TO OSHOGBO	58.	4.80
57.	IFE TO ILESHA	32.	3.50
58.	IFE TO ONDO	61.	5.00
59.	IKEJA TO LAGOS	19.	3.80
60.	IKEJA TO ILARO	54.	4.50
61.	IKEJA TO ABEOKUTA	83.	5.40
62.	SHAGAMU TO LAGOS	68.	5.00
63.	IJEBU ODE TO LAGOS	100.	5.00

SAMPLE OBTAINED WITH KADUNA AS LOADING POINT

NO.	NAME CF TOWN	DiJ(Km)	CiJ(N)
1.	ABA	969.	34.14
2.	ABUJA	416.	14.65
3.	AGAIE	370.	13.03
4.	ARGUNGU	547.	19.27
5.	AZARE	375.	13.21
6.	BACITA	538.	18.95
7.	BAMA	951.	33.50
8.	BAUCHI	412.	14.51
9.	BENIN	788.	27.76
10.	BIDA	333.	11.73
11.	BIRNIN GWARI	115.	4.05
12.	BIRNIN KEBBI	600.	21.13
13.	BIRNIN KUDU	396.	13.95
14.	BIU	879.	30.96
15.	BUKURU	304.	10.71
16.	CALABAR	1036.	36.50
17.	DANBATTA	337.	11.87
18.	DAURA	518.	18.25
19.	ENUGU	774.	27.27
20.	FUNTUA	156.	5.50
21.	GASHUA	911.	32.09
22.	GBOKO	594.	20.93
23.	GOMBE	568.	20.01
24.	GUMEL	388.	13.67
25.	GUSAU	269.	9.48
26.	HADEIJA	468.	16.49
27.	IBADAN	758.	26.70
28.	IFE	750.	26.42
29.	ILORIN	599.	21.10
30.	JEBBA	489.	17.22
31.	JOS	280.	9.86
32.	KABBA	592.	20.86
33.	KACHIA	113.	3.98
34.	KAFANCHAN	224.	7.89
35.	KANO	262.	9.23
36.	KATSINA	436.	15.36
37.	KAZAURE	337.	11.87
38.	KEFFI	272.	9.58
39.	KOKO	868.	30.58
40.	KONTAGORA	303.	10.67
41.	LAFIA	403.	14.20
42.	LOKOJA	505.	17.79
43.	MAIDUGURI	876.	30.80
44.	MAKURDI	502.	17.68
45.	MALUMFASHI	204.	7.19
46.	MINNA	229.	10.53
47.	MISAU	538.	18.95
48.	MUBI	1064.	37.48
49.	NGURU	987.	34.45
50.	NKALAGU	785.	27.66

51.	NSUKKA	716.	25.22
52.	NUMAN	762.	26.84
53.	OFFA	663.	23.36
54.	OGBOMOSHO	653.	23.00
55.	OJI RIVER	796.	28.04
56.	OKENE	578.	20.36
57.	ONDO	832.	29.31
58.	ONITSHA	861.	30.33
59.	OTURKPO	621.	21.88
60.	OWERRI	912.	32.13
61.	OYO	705.	24.84
62.	PORT HARCOURT	1009.	35.55
63.	POTISKUN	641.	22.58
64.	SAPELE	846.	29.80
65.	SOKOTO	483.	17.02
66.	WARRI	896.	31.57
67.	YOLA	822.	28.96
68.	ZARIA	84.	2.96
69.	ZUNGERU	240.	8.46

SAMPLE OBTAINED WITH KANO AS LOADING POINT

NO.	NAME OF TOWN	Dij(Km)	Cij(N)
1.	ABA	1231.	22.50
2.	ABAK	1224.	20.60
3.	ABAKALIKI	1109.	15.57
4.	ABEOKUTA	1088.	20.45
5.	AFIKPO	1204.	25.20
6.	AGBOR	1012.	19.50
7.	AKURE	1048.	18.85
8.	ASABA	1133.	16.75
9.	AWGU	1081.	17.54
10.	BENIN	1051.	19.70
11.	CALABAR	1298.	23.00
12.	ENUGU	1035.	18.15
13.	FUNTUA	212.	5.37
14.	GOMBE	459.	9.49
15.	GUSAU	328.	8.75
16.	IBADAN	1007.	19.50
17.	LOKOJA	768.	13.07
18.	IFE	999.	19.85
19.	IJEBU ODE	1076.	21.30
20.	IKOM	1264.	22.48
21.	IKOT EKPENE	1200.	22.50
22.	IKEJA	1141.	20.63
23.	ILESHA	995.	17.43
24.	ILORIN	848.	14.26
25.	JOS	420.	6.45
26.	KADUNA	262.	3.50
27.	KATSINA	174.	2.77
28.	LAGOS	1151.	18.00
29.	MAIDUGURI	576.	7.80
30.	MINNA	505.	7.50
31.	NSUKKA	978.	15.25
32.	OBUBRA	1152.	22.50
33.	ONITSHA	1123.	16.75
34.	ONDO	1081.	22.00
35.	OGBOMOSHO	903.	15.88
36.	ORON	1294.	23.40
37.	OSHOGBO	962.	14.50
38.	OTURKPO	883.	13.78
39.	OWERRI	1175.	20.65
40.	OWO	935.	16.41
41.	OYO	954.	14.50
42.	PORT HARCOURT	1271.	22.50
43.	SAPELE	1109.	15.60
44.	SHAGAMU	1083.	20.50
45.	SOKOTO	549.	7.55
46.	UMUAHIA	1155.	20.40
47.	UYO	1239.	23.10
48.	WARRI	1158.	16.40
49.	YOLA	712.	13.75
50.	ZARIA	79.	2.50

SAMPLE OBTAINED WITH LAGOS AS LOADING POINT

NO.	NAME OF TOWN	Dij(Km)	Cij(N)
1.	ABA	641.	22.58
2.	ABUJA	854.	30.08
3.	AGAIE	605.	21.31
4.	ARGUNGU	1099.	38.72
5.	AZARE	1264.	44.53
6.	BACITA	461.	16.24
7.	BAMA	1752.	61.72
8.	BAUCHI	1213.	42.73
9.	BENIN	333.	11.73
10.	BIDA	568.	20.01
11.	BIRNIN GWARI	786.	27.69
12.	BIRNIN KEBBI	1152.	40.58
13.	BIRNIN KUDU	1285.	45.27
14.	BIU	1680.	59.19
15.	BUKURU	1106.	38.96
16.	CALABAR	784.	27.62
17.	DANBATTA	1226.	43.19
18.	DAURA	1294.	45.59
19.	ENUGU	591.	20.82
20.	FUNTUA	1136.	40.02
21.	GASHUA	1712.	60.31
22.	GBOKO	979.	34.49
23.	GOMBE	1369.	48.23
24.	GUMEL	1277.	49.99
25.	GUSAU	897.	34.77
26.	HADEIJA	1351.	47.60
27.	IBADAN	143.	5.04
28.	IFE	230.	8.10
29.	ILORIN	303.	10.67
30.	JEBBA	412.	14.51
31.	JOS	1082.	38.12
32.	KABBA	454.	15.99
33.	KACHIA	1014.	35.72
34.	KADUNA	901.	31.74
35.	KAFANCHAN	1125.	39.63
36.	KANO	1151.	40.55
37.	KATSINA	1212.	42.70
38.	KAZAWA	1226.	43.19
39.	KEFFI	1173.	41.32
40.	KOKO	413.	14.55
41.	KONTAGORA	599.	21.10
42.	LAFIA	788.	27.76
43.	LOKOJA	542.	19.09
44.	MAIDUGURI	1677.	59.08
45.	MAKURDI	877.	31.25
46.	MALUMFASHI	1144.	40.30
47.	MINNA	737.	25.95
48.	MISSAU	1427.	50.27
49.	MUBI	1765.	62.18
50.	NGURU	1779.	62.67

51.	NKALAGU	632.	22.27
52.	NSUKKA	628.	22.12
53.	NUMAN	1382.	48.69
54.	OFFA	367.	12.93
55.	OGBOMOSHO	254.	8.95
56.	OJI RIVER	547.	19.27
57.	OKENE	472.	16.63
58.	ONDO	246.	8.67
59.	ONITSHA	483.	17.02
60.	OTURKPO	729.	25.68
61.	OWERRI	576.	20.29
62.	OYO	196.	6.91
63.	PORT HARCOURT	689.	24.27
64.	POTISKUN	1442.	50.80
65.	SAPELE	385.	13.56
66.	SOKOTO	1035.	36.46
67.	WARRI	435.	15.32
68.	YOLA	1442.	50.80
69.	ZARIA	985.	34.70
70.	ZUNGERU	687.	23.89

APPENDIX II

LINK	FROM	TO	DIST(Km)	COST1	COST2
1.	IKEJA ROAD	LAGOS ROAD	19.0	3.80	1.33
2.	ILARO ROAD	IKEJA ROAD	54.0	4.50	3.78
3.	ABEOKUTA ROAD	IKEJA ROAD	83.0	5.40	5.81
4.	SHAGAMU	LAGOS ROAD	68.0	5.00	4.76
5.	IJEBU ODE	LAGOS ROAD	100.0	6.00	7.00
6.	ABEOKUTA ROAD	ILARO ROAD	60.0	3.89	4.20
7.	SHAGAMU	ABEOKUTA ROAD	51.0	3.64	3.57
8.	ERUWA	ABEOKUTA ROAD	65.0	4.03	4.55
9.	IBADAN ROAD	ABEOKUTA ROAD	77.0	5.00	5.39
10.	IBADAN ROAD	LAGOS ROAD	143.0	8.20	9.58
11.	SHAGAMU	IBADAN ROAD	76.0	5.30	5.32
12.	IJEBU ODE	SHAGAMU	32.0	3.11	4.24
13.	IJEBU ODE	IBADAN ROAD	69.0	5.20	4.83
14.	IJEBU ODE	ONDO	153.0	6.49	10.71
15.	IJEBU ODE	OKITIPUPA	141.0	6.16	9.87
16.	IFE	IBADAN ROAD	89.0	5.50	6.23
17.	IWO	IBADAN ROAD	42.0	4.40	2.94
18.	OYO	IBADAN ROAD	53.0	4.50	3.71
19.	ERUWA	IBADAN ROAD	53.0	5.00	3.71
20.	OYO	ERUWA	103.0	5.08	7.21
21.	IWO	OYO	43.0	3.41	3.01
22.	OYO	OGBOMOSHO	53.0	3.69	3.71
23.	IWO	OGBOMOSHO	96.0	4.90	6.72
24.	IFE	IWO	52.0	4.50	3.64
25.	IFE	OGBOMOSHO	92.0	5.70	6.44
26.	OGBOMOSHO	OSHOGBO ROAD	56.0	3.78	3.92
27.	OGBOMOSHO	IKIRUN ROAD	56.0	3.78	3.92
28.	IKIRUN ROAD	OSHOGBO ROAD	21.0	2.80	1.47
29.	IFE	OSHOGBO ROAD	58.0	4.80	4.06
30.	ILESHA	OSHOGBO ROAD	32.0	3.11	2.24
31.	ILESHA	IJEBU IJESHA	10.0	2.49	.70
32.	IJEBU IJESHA	IKIRUN ROAD	52.0	3.67	3.64
33.	IJERO EKITI	IKURUN ROAD	50.0	3.61	3.50
34.	IJERO EKITI	IJEBU IJESHA	34.0	3.16	2.38
35.	IJEBU IJESHA	ADO EKITI	56.0	3.78	3.92
36.	ILESHA	AKURE	85.0	4.59	5.95
37.	ONDO	ILESHA	87.0	4.65	6.09
38.	IFE	ILESHA	32.0	3.50	2.24
39.	IFE	ONDO	61.0	5.80	4.27
40.	ONDO	AKURE	51.0	3.64	3.57
41.	ONDO	OKITIPUPA	74.0	4.82	5.18
42.	IKOLE	IJERO EKITI	54.0	3.72	3.78
43.	IJERO EKITI	ADO EKITI	43.0	3.41	3.01
44.	IKERRE	ADO EKITI	16.0	2.66	1.12
45.	IKERRE	AKURE	30.0	3.05	2.10
46.	AKURE	OWO	50.0	3.61	3.50
47.	IKERRE	OWO	62.0	3.95	4.34
48.	IKARE	ADO EKITI	62.0	3.95	4.34
49.	IKOLE	ADO EKITI	53.0	3.69	3.71

50.	IKARE	IKOLE	55.0	3.75	3.85
51.	IKARE	OWO	45.0	3.47	3.15
52.	OKITIPUPA	BENIN	142.0	7.00	9.62
53.	ONDO	BENIN	167.0	7.50	10.91
54.	OWO	BENIN	120.0	6.40	8.20
55.	IKARE	IGARRA	54.0	3.72	3.78
56.	OWO	IGARRA	76.0	4.34	5.32
57.	OWO	SABONGIDA ORA	67.0	4.09	4.69
58.	IGARRA	AUCHI	30.0	3.05	2.10
59.	SABONGIDA ORA	AUCHI	40.0	3.33	2.80
60.	AUCHI	AGENEBODE ROAD	53.0	3.69	3.71
61.	SABONGIDA ORA	BENIN	118.0	6.50	8.08
62.	AUCHI	BENIN	134.0	6.80	9.10
63.	AUCHI	UBIAJA	57.0	3.81	3.99
64.	BENIN	UBIAJA	109.0	6.20	7.54
65.	AGBOR	UBIAJA	60.0	3.89	4.20
66.	ABUDU	AGBOR	15.0	2.63	1.05
67.	ABUDU	BENIN	54.0	4.50	3.78
68.	BENIN	SAPELE	52.0	4.60	3.64
69.	AGBOR	SAPELE	119.0	5.54	8.33
70.	SAPELE	WARRI ROAD	39.0	3.30	2.73
71.	AGBOR	WARRI ROAD	121.0	5.60	8.47
72.	UGHELLI	WARRI ROAD	33.0	3.13	2.31
73.	UGHELLI	ONITSHA ROAD	164.0	7.50	10.84
74.	AGBOR	ONITSHA ROAD	70.0	5.00	4.90
75.	AHOADA	ONITSHA ROAD	135.0	5.99	9.45
76.	AHOADA	YENEGOA ROAD	48.0	3.55	3.36
77.	AHOADA	DEGEMA ROAD	44.0	3.44	3.08
78.	AHOADA	P. H. ROAD	61.0	4.80	4.27
79.	AHOADA	OWERRI	75.0	4.31	5.25
80.	OWERRI	ONITSHA ROAD	79.0	5.00	5.53
81.	ORLU	ONITSHA ROAD	55.0	4.90	3.85
82.	AWKA	ONITSHA ROAD	37.0	4.00	2.59
83.	NSUKKA	IDAH ROAD	78.0	5.40	5.46
84.	AWKA	NSUKKA	108.0	6.00	7.56
85.	NSUKKA	ENUGU ROAD	58.0	4.00	4.06
86.	AWKA	ENUGU ROAD	71.0	5.00	4.97
87.	AWGU	ENUGU ROAD	42.0	4.70	2.94
88.	AWKA	AWGU	66.0	5.00	4.62
89.	AWGU	OKIGWI	35.0	3.19	2.45
90.	AWKA	OKIGWI	72.0	5.50	5.04
91.	AWKA	ORLU	52.0	4.88	3.64
92.	OKIGWI	ORLU	44.0	3.44	3.08
93.	ORLU	OWERRI	38.0	4.30	2.66
94.	OKIGWI	OWERRI	58.0	3.83	4.06
95.	OWERRI	UMUAHIA ROAD	62.0	4.70	4.34
96.	OWERRI	ABA ROAD	61.0	4.80	4.27
97.	OWERRI	P. H. ROAD	113.0	5.20	7.78
98.	ABA ROAD	P. H. ROAD	64.0	4.50	4.84
[illegible]	BORI	P. H. ROAD	43.0	3.41	3.01
1[illegible]	OPOBO	BORI	24.0	2.88	1.68
101.	BORI	ABA ROAD	88.0	4.67	6.16
102.	ABAK	OPOBO	58.0	3.83	4.06
103.	ABAK	ABA ROAD	48.0	3.53	3.36

104.	IKOT EKPENE	ABAK	24.0	2.88	1.68
105.	IKOT EKPENE	ABA ROAD	42.0	3.39	2.94
106.	UMUAHIA ROAD	ABA ROAD	55.0	4.70	3.85
107.	IKOT EKPENE	UMUAHIA ROAD	45.0	3.47	3.15
108.	AFIKPO	UMUAHIA ROAD	80.0	4.45	5.60
109.	OKIGWI	UMUAHIA ROAD	48.0	3.55	3.36
110.	OKIGWI	AFIKPO	71.0	4.20	4.97
111.	AFIKPO	ENUGU ROAD	147.0	7.00	9.57
112.	ENUGU ROAD	ABAKALIKI	81.0	5.50	5.67
113.	AFIKPO	ABAKALIKI	61.0	3.92	4.27
114.	OGOJA	ABAKALIKI	123.0	5.65	8.61
115.	OGOJA	OBUBRA	140.0	6.13	9.80
116.	OBUBRA	ABAKALIKI	43.0	3.41	3.01
117.	AFIKPO	OBUBRA	96.0	4.90	6.72
118.	OGOJA	OBUDU	56.0	3.78	3.92
119.	IKOM	OBUDU	118.0	5.51	8.26
120.	IKOM	OGOJA	88.0	4.67	6.16
121.	IKOM	OBUBRA	56.0	3.78	3.92
122.	IKOM	AKAMKPA	171.0	7.00	11.79
123.	AKAMKPA	OBUBRA	123.0	5.65	8.61
124.	AFIKPO	AKAMKPA	115.0	5.43	8.05
125.	ITU	AFIKPO	110.0	5.29	7.70
126.	ITU	AKAMKPA	54.0	3.72	3.78
127.	IKOT EKPENE	ITU	38.0	3.27	2.66
128.	IKOT EKPENE	UYO	30.0	3.05	2.10
129.	ITU	UYO	20.0	2.77	1.40
130.	CALABAR ROAD	AKAMKPA	40.0	4.20	2.80
131.	CALABAR ROAD	IKOM	152.0	9.20	10.18
132.	ABAK	UYO	16.0	2.60	1.12
133.	EKET	OPOBO	45.0	3.47	3.15
134.	EKET	ETINAM	31.0	3.08	2.17
135.	ETINAM	UYO	16.0	3.70	1.12
136.	EKET	ORON	45.0	4.40	3.15
137.	ORON	UYO	52.0	4.60	3.64
138.	CALABAR	ORON	24.0	4.50	4.50
139.	IKEJA RAIL	LAGOS RAIL	18.0	3.15	3.15
140.	ILARO RAIL	IKEJA RAIL	61.0	3.85	3.85
141.	ABEOKUTA RAIL	IKEJA RAIL	83.0	4.25	4.25
142.	ABEOKUTA RAIL	ILARO RAIL	88.0	4.25	4.25
143.	IBADAN RAIL	ABEOKUTA RAIL	96.0	4.40	4.40
144.	OSHOGBO RAIL	IBADAN RAIL	100.0	4.55	4.55
145.	IKIRUN RAIL	OSHOGBO RAIL	19.0	3.15	3.15
146.	ABA RAIL	P. H. RAIL	63.0	3.85	3.85
147.	UMUAHIA RAIL	ABA RAIL	50.0	3.70	3.70
148.	ENUGU RAIL	UMUAHIA RAIL	130.0	5.10	5.10
149.	IDAH RIVER	ONITSHA RIVER	113.0	2.32	2.32
150.	ONITSHA RIVER	AGENEBODE RIVER	113.0	2.32	2.32
151.	ONITSHA RIVER	WARRI RIVER	313.0	7.62	7.62
152.	ONITSHA RIVER	YENEGOA RIVER	186.0	7.93	7.93
153.	DEGEMA RIVER	YENEGOA RIVER	86.0	8.25	8.25
154.	DEGEMA RIVER	P. H. PORT	37.0	.96	.96
155.	LAGOS PORT	LAGOS RAIL	NIL	1.16	1.16
156.	LAGOS PORT	LAGOS ROAD	NIL	1.17	1.17
157.	LAGOS RAIL	LAGOS ROAD	NIL	2.33	2.33

158.	LAGOS ROAD	LAGOS RAIL	NIL	2.33	2.33
159.	IKEJA INDUSTRY	IKEJA RAIL	NIL	1.16	1.16
160.	IKEJA INDUSTRY	IKEJA ROAD	NIL	1.15	1.15
161.	IKEJA RAIL	IKEJA ROAD	NIL	2.31	2.31
162.	IKEJA ROAD	IKEJA RAIL	NIL	1.16	1.16
163.	ILARO	ILARO RAIL	NIL	1.16	1.16
164.	ILARO	ILARO ROAD	NIL	2.07	2.07
165.	ILARO RAIL	ILARO ROAD	NIL	2.07	2.07
166.	ILARO ROAD	ILARO RAIL	NIL	1.16	1.16
167.	ABEOKUTA	ABEOKUTA RAIL	NIL	1.04	1.04
168.	ABEOKUTA	ABEOUKUTA ROAD	NIL	2.20	2.20
169.	ABEOKUTA RAIL	ABEOKUTA ROAD	NIL	2.20	2.20
170.	ABEOKUTA ROAD	ABEOKUTA RAIL	NIL	1.16	1.16
171.	IBADAN	IBADAN RAIL	NIL	1.04	1.04
172.	IBADAN	IBADAN ROAD	NIL	2.20	2.20
173.	IBADAN RAIL	IBADAN ROAD	NIL	2.20	2.20
174.	IBADAN ROAD	IBADAN RAIL	NIL	1.16	1.16
175.	OSHOGBO	OSHOGBO RAIL	NIL	.91	.91
176.	OSHOGBO	OSHOGBO ROAD	NIL	2.07	2.07
177.	OSHOGBO RAIL	OSHOGBO ROAD	NIL	2.07	2.07
178.	OSHOGBO ROAD	OSHOGBO RAIL	NIL	1.16	1.16
179.	IKIRUN	IKIRUN RAIL	NIL	.79	.79
180.	IKIRUN	IKIRUN ROAD	NIL	1.95	1.95
181.	IKIRUN RAIL	IKIRUN ROAD	NIL	1.95	1.95
182.	IKIRUN ROAD	IKIRUN RAIL	NIL	1.95	1.95
183.	PORT HARCOURT	P. H. RAIL	NIL	1.16	1.16
184.	PORT HARCOURT	P. H. ROAD	NIL	1.17	1.17
185.	P. H. RAIL	P. H. ROAD	NIL	2.33	2.33
186.	P. H. ROAD	P. H. RAIL	NIL	2.33	2.33
187.	PORT HARCOURT	P. H. PORT	NIL	.96	.96
188.	P. H. PORT	P. H. RAIL	NIL	1.16	1.16
189.	P. H. PORT	P. H. ROAD	NIL	1.17	1.17
190.	P. H. RAIL	P. H. ROAD	NIL	2.33	2.33
191.	P. H. ROAD	P. H. RAIL	NIL	2.33	2.33
192.	ABA	ABA RAIL	NIL	1.16	1.16
193.	ABA	ABA ROAD	NIL	.91	.91
194.	ABA ROAD	ABA RAIL	NIL	2.07	2.07
195.	ABA RAIL	ABA ROAD	NIL	2.07	2.07
196.	UMUAHIA	UMUAHIA RAIL	NIL	1.16	1.16
197.	UMUAHIA	UMUAHIA ROAD	NIL	.91	.91
198.	UMUAHIA RAIL	UMUAHIA ROAD	NIL	2.07	2.07
199.	UMUAHIA ROAD	UMIAHIA RAIL	NIL	2.07	2.07
200.	ENUGU	ENUGU RAIL	NIL	1.16	1.16
201.	ENUGU RAIL	ENUGU ROAD	NIL	1.17	1.17
202.	ENUGU RAIL	ENUGU ROAD	NIL	2.33	2.33
203.	ENUGU ROAD	ENUGU RAIL	NIL	2.33	2.33
204.	IDAH RIVER	IDAH ROAD	NIL	1.91	1.91
205.	IDAH RIVER	AGENEBODE RIVER	NIL	.01	.01
206.	AGENEBODE RIVER	AGENEBODE ROAD	NIL	1.91	1.91
207.	ONITSHA	ONITSHA RIVER	NIL	.91	.91
208.	ONITSHA	ONITSHA ROAD	NIL	.91	.91
209.	ONITSHA RIVER	ONITSHA ROAD	NIL	1.82	1.82
210.	ONITSHA ROAD	ONITSHA RIVER	NIL	1.82	1.82
211.	WARRI	WARRI ROAD	NIL	.91	.91

212.	WARRI	WARRI RIVER/PORT	NIL	.91	.91
213.	WARRI RIVER	WARRI ROAD	NIL	1.82	1.82
214.	WARRI ROAD	WARRI RIVER	NIL	1.82	1.82
215.	YENEGOA	YENEGOA RIVER	NIL	.79	.79
216.	YENEGOA	YENEGOA ROAD	NIL	.79	.79
217.	YENEGOA RIVER	YENEGOA ROAD	NIL	1.58	1.58
218.	YENEGOA ROAD	YENEGOA RIVER	NIL	1.58	1.58
219.	DEGEMA ROAD	DEGEMA RIVER	NIL	.91	.91
220.	SAPELE	SAPELE PORT	NIL	.91	.91
222.	CALABAR	CALABAR PORT	NIL	.91	.91
223.	ABAK	ABAK (PALMIL)	NIL	.91	.91
224.	ORLU	ORLU (NIPROC)	NIL	1.50	1.50
225.	AWKA	AWKA (PALMKE)	NIL	2.50	2.50
226.	IBADAN	LAGOS PORT	144.0	9.52	9.64
227.	IFE	LAGOS PORT	233.0	14.50	14.98
228.	ABEOKUTA	LAGOS PORT	102.0	7.74	7.12
229.	IJEBU ODE	LAGOS PORT	100.0	7.06	7.00
230.	IWO	LAGOS PORT	186.0	13.28	12.16
231.	ONDO	LAGOS PORT	253.0	18.05	16.17
232.	IKIRUN	LAGOS PORT	312.0	16.65	19.10
233.	SHAGAMU	LAGOS PORT	68.0	5.00	4.76
234.	OKITIPUPA	LAGOS PORT	241.0	16.30	15.46
235.	OSHOGBO	LAGOS PORT	291.0	16.20	18.05
236.	ILESHA	LAGOS PORT	265.0	14.50	16.45
237.	ILARO	LAGOS PORT	73.0	6.28	5.11
238.	IKARE	LAGOS PORT	399.0	24.15	23.45
239.	IKOLE	LAGOS PORT	363.0	23.72	21.75
240.	IJERO EKITI	LAGOS PORT	309.0	19.50	18.95
241.	OYO	LAGOS PORT	197.0	12.40	12.82
242.	IJEBU IJESHA	LAGOS PORT	275.0	11.64	16.75
243.	OGBOMOSHO	LAGOS PORT	250.0	10.88	16.00
244.	IKERRE	LAGOS PORT	344.0	21.55	20.20
245.	AKURE	LAGOS PORT	304.0	20.60	18.70
246.	ADO EKITI	LAGOS PORT	350.0	20.65	21.00
247.	OWO	LAGOS PORT	354.0	23.00	21.35
248.	ERUWA	LAGOS PORT	167.0	10.90	11.02
249.	ABUDU	LAGOS PORT	437.0	16.56	25.35
250.	AGBOR	LAGOS PORT	452.0	17.02	26.10
251.	SABONGIDA ORA	LAGOS PORT	501.0	18.51	21.05
252.	AUCHI	LAGOS PORT	517.0	19.00	29.35
253.	BENIN	LAGOS PORT	383.0	15.00	22.65
254.	IGARRA	LAGOS PORT	547.0	19.91	30.85
255.	SALELE	LAGOS PORT	435.0	16.50	25.25
256.	UBIAJA	LAGOS PORT	492.0	18.24	28.10
257.	UGHELLI	LAGOS PORT	507.0	18.64	21.35
258.	WARRI	LAGOS PORT	517.0	19.00	29.35
259.	AWKA	LAGOS PORT	559.0	20.27	31.45
260.	NSUKKA	LAGOS PORT	667.0	23.56	38.85
261.	ONITSHA	LAGOS PORT	522.0	19.15	29.60
262.	ENUGU	LAGOS PORT	630.0	21.26	35.00
263.	AWGU	LAGOS PORT	625.0	22.28	34.75
264.	ABA	LAGOS PORT	662.0	23.40	36.60
265.	UMUAHIA	LAGOS PORT	663.0	23.44	36.65
266.	OKIGWI	LAGOS PORT	621.0	22.16	34.55

267.	ORLU	LAGOS PORT	577.0	20.18	32.55
268.	OWERRI	LAGOS PORT	601.0	21.55	33.55
269.	AFIKPO	LAGOS PORT	692.0	24.32	38.10
270.	ABAK	LAGOS PORT	805.0	27.75	43.75
271.	AKAMKPA	LAGOS PORT	796.0	27.48	43.30
272.	CALABAR	LAGOS PORT	836.0	29.37	45.30
273.	EKET	LAGOS PORT	773.0	26.78	42.15
274.	ETINAM	LAGOS PORT	742.0	25.84	40.60
275.	IKOT EKPENE	LAGOS PORT	704.0	24.68	29.70
276.	ITU	LAGOS PORT	742.0	24.84	40.60
277.	IKOM	LAGOS PORT	844.0	28.94	45.70
278.	OBUBRA	LAGOS PORT	839.0	28.79	45.45
279.	OBUDU	LAGOS PORT	890.0	30.34	48.00
280.	OGOJA	LAGOS PORT	834.0	28.63	45.20
281.	OPOBO	LAGOS PORT	774.0	26.81	42.20
282.	ORON	LAGOS PORT	778.0	26.93	42.40
283.	UYO	LAGOS PORT	742.0	25.84	40.60
284.	PORT HARCOURT	LAGOS PORT	714.0	24.99	39.20
285.	AHOADA	LAGOS PORT	657.0	23.25	36.35
286.	DEGEMA	LAGOS PORT	701.0	24.59	38.55
287.	YENEGOA	LAGOS PORT	705.0	24.71	38.75
288.	BORI	LAGOS PORT	750.0	26.08	41.00
289.	ABAKALIKI	LAGOS PORT	711.0	24.89	39.05
290.	IBADAN	SAPELE PORT	404.0	19.40	23.70
291.	IFE	SAPELE PORT	280.0	11.79	17.50
292.	ABEOKUTA	SAPELE PORT	418.0	15.99	24.40
293.	IJEBU ODE	SAPELE PORT	335.0	13.46	20.25
294.	IWO	SAPELE PORT	332.0	13.37	21.10
295.	ONDO	SAPELE PORT	219.0	9.94	14.14
296.	IKIRUN	SAPELE PORT	359.0	14.19	21.45
297.	SHAGAMU	SAPELE PORT	367.0	14.44	21.85
298.	OKITIPUPA	SAPELE PORT	194.0	9.18	12.64
299.	OSHOGBO	SAPELE PORT	338.0	13.56	20.40
300.	ILESHA	SAPELE PORT	306.0	12.58	17.80
301.	ILARO	SAPELE PORT	478.0	17.81	27.40
302.	IKARE	SAPELE PORT	217.0	9.98	14.02
303.	IKOLE	SAPELE PORT	272.0	11.55	17.32
304.	IJERO EKITI	SAPELE PORT	293.0	12.19	15.29
305.	OYO	SAPELE PORT	375.0	14.68	22.25
306.	IJEBU IJESHA	SAPELE PORT	316.0	12.89	19.30
307.	OGBOMOSHO	SAPELE PORT	372.0	14.59	22.10
308.	IKERRE	SAPELE PORT	234.0	10.39	15.04
309.	AKURE	SAPELE PORT	222.0	10.03	14.32
310.	ADO EKITI	SAPELE PORT	250.0	10.88	16.00
311.	OWO	SAPELE PORT	172.0	8.51	11.32
312.	ERUWA	SAPELE PORT	422.0	16.11	24.60
313.	ABUDU	SAPELE PORT	106.0	6.50	7.36
314.	AGBOR	SAPELE PORT	121.0	6.69	8.26
315.	SABONGIDA ORA	SAPELE PORT	170.0	8.45	11.20
316.	AUCHI	SAPELE PORT	186.0	9.50	12.16
317.	BENIN	SAPELE PORT	64.0	4.66	3.64
318.	IGARRA	SAPELE PORT	216.0	9.95	13.96
319.	UBIAJA	SAPELE PORT	161.0	8.17	10.66
320.	UGHELLI	SAPELE PORT	72.0	5.47	5.04

321.	WARRI	SAPELE PORT	39.0	4.47	2.73
322.	AWKA	SAPELE PORT	228.0	10.21	14.68
323.	NSUKKA	SAPELE PORT	336.0	13.49	20.30
324.	ONITSHA	SAPELE PORT	191.0	9.09	12.46
325.	ENUGU	SAPELE PORT	299.0	12.60	18.45
326.	AWGU	SAPELE PORT	294.0	12.22	18.20
327.	ABA	SAPELE PORT	331.0	13.34	20.05
328.	UMUAHIA	SAPELE PORT	332.0	13.37	20.10
339.	OKIGWI	SAPELE PORT	290.0	12.10	18.00
330.	ORLU	SAPELE PORT	246.0	10.76	15.76
331.	OWERRI	SAPELE PORT	270.0	11.49	17.00
332.	AFIKPO	SAPELE PORT	361.0	14.25	21.55
333.	ABAK	SAPELE PORT	379.0	14.80	22.45
334.	AKAMKPA	SAPELE PORT	465.0	17.42	26.75
335.	CALABAR	SAPELE PORT	505.0	18.63	28.75
336.	EKET	SAPELE PORT	442.0	16.72	25.60
337.	ETINAM	SAPELE PORT	411.0	15.77	25.05
338.	IKOT EKPENE	SAPELE PORT	373.0	14.62	22.25
339.	ITU	SAPELE PORT	411.0	15.77	24.05
340.	IKOM	SAPELE PORT	479.0	17.84	29.05
341.	OBUBRA	SAPELE PORT	508.0	18.72	28.90
342.	OBUDU	SAPELE PORT	559.0	20.27	31.45
343.	OGOJA	SAPELE PORT	503.0	18.57	28.65
344.	OPOBO	SAPELE PORT	443.0	16.75	25.65
345.	ORON	SAPELE PORT	447.0	16.87	25.75
346.	UYO	SAPELE PORT	395.0	15.29	23.25
347.	PORT HARCOURT	SAPELE PORT	383.0	14.02	22.65
348.	AHOADA	SAPELE PORT	326.0	13.19	19.80
349.	DEGEMA	SAPELE PORT	370.0	14.53	22.00
350.	YENEGOA	SAPELE PORT	374.0	14.65	22.20
351.	BORI	SAPELE PORT	419.0	16.02	24.45
352.	ABAKALIKI	SAPELE PORT	323.0	13.10	19.65
353.	IBADAN	WARRI PORT	443.0	16.23	25.65
354.	IFE	WARRI PORT	318.0	12.98	19.45
355.	ABEOKUTA	WARRI PORT	457.0	17.17	26.35
356.	IJEBU ODE	WARRI PORT	374.0	14.65	22.20
357.	IWO	WARRI PORT	371.0	14.56	22.05
358.	ONDO	WARRI PORT	258.0	11.12	16.40
359.	IKIRUN	WARRI PORT	398.0	15.38	23.40
360.	SHAGAMU	WARRI PORT	406.0	15.62	23.80
361.	OKITIPUPA	WARRI PORT	233.0	10.36	14.98
362.	OSHOGBO	WARRI PORT	377.0	14.72	22.35
363.	ILESHA	WARRI PORT	345.0	13.77	20.75
364.	ILARO	WARRI PORT	517.0	19.00	29.35
365.	IKARE	WARRI PORT	518.0	11.06	16.30
366.	IKOLE	WARRI PORT	311.0	12.73	19.05
367.	IJERO EKITI	WARRI PORT	334.0	13.43	20.20
368.	OYO	WARRI PORT	414.0	15.87	24.20
369.	IJEBU IJESHA	WARRI PORT	355.0	14.07	21.25
370.	OGBOMOSHO	WARRI PORT	411.0	15.77	24.05
371.	IKERRE	WARRI PORT	273.0	11.58	17.15
372.	AKURE	WARRI PORT	261.0	11.21	16.55
373.	ADO EKITI	WARRI PORT	289.0	12.07	17.95
374.	OWO	WARRI PORT	211.0	9.69	13.66

375.	ERUWA	WARRI PORT	461.0	17.29	26.55
376.	ABUDU	WARRI PORT	136.0	7.41	9.61
377.	AGBOR	WARRI PORT	121.0	6.96	8.26
378.	SABONGIDA ORA	WARRI PORT	209.0	9.63	13.54
379.	AUCHI	WARRI PORT	225.0	14.12	14.50
380.	BENIN	WARRI PORT	91.0	6.00	6.37
381.	IGARRA	WARRI PORT	255.0	14.00	16.25
382.	SAPELE	WARRI PORT	39.0	4.47	2.73
383.	UBIAJA	WARRI PORT	181.0	8.78	11.86
384.	UGHELLI	WARRI PORT	33.0	4.28	2.21
385.	AWKA	WARRI PORT	271.0	11.52	17.05
386.	NSUKKA	WARRI PORT	336.0	15.49	20.30
387.	ONITSHA	WARRI PORT	191.0	9.09	12.46
388.	ENUGU	WARRI PORT	299.0	11.59	18.45
389.	AWGU	WARRI PORT	294.0	12.22	18.20
390.	ABA	WARRI PORT	331.0	13.34	20.05
391.	UMUAHIA	WARRI PORT	332.0	13.37	20.10
392.	OKIGWI	WARRI PORT	300.0	15.38	18.55
393.	ORLU	WARRI PORT	246.0	13.76	15.76
394.	OWERRI	WARRI PORT	270.0	11.49	17.00
395.	AFIKPO	WARRI PORT	361.0	14.25	21.55
396.	ABAK	WARRI PORT	379.0	14.80	22.45
397.	AKAMKPA	WARRI PORT	465.0	17.42	26.75
398.	CALABAR	WARRI PORT	505.0	18.63	28.75
399.	EKET	WARRI PORT	442.0	16.72	25.60
400.	ETINAM	WARRI PORT	411.0	15.77	24.05
401.	IKOT EKPENE	WARRI PORT	373.0	14.62	22.15
402.	ITU	WARRI PORT	411.0	15.77	24.05
403.	IKOM	WARRI PORT	479.0	17.84	27.25
404.	OBUBRA	WARRI PORT	411.0	18.72	28.90
405.	OBUDU	WARRI PORT	559.0	20.27	31.45
406.	OGOJA	WARRI PORT	503.0	18.57	28.65
407.	OPOBO	WARRI PORT	443.0	16.75	25.65
408.	ORON	WARRI PORT	447.0	16.87	25.85
409.	UYO	WARRI PORT	395.0	15.29	23.25
410.	PORT HARCOURT	WARRI PORT	383.0	14.92	22.65
411.	AHOADA	WARRI PORT	205.0	9.51	13.30
412.	DEGEMA	WARRI PORT	370.0	14.53	22.00
413.	YENEGOA	WARRI PORT	374.0	14.65	22.20
414.	BORI	WARRI PORT	419.0	16.02	22.45
415.	ABAKALIKI	WARRI PORT	380.0	14.82	22.50
416.	IBADAN	PORT HARCOURT	684.0	26.35	35.90
417.	IFE	PORT HARCOURT	559.0	20.27	31.45
418.	ABEOKUTA	PORT HARCOURT	697.0	24.47	38.35
419.	IJEBU ODE	PORT HARCOURT	614.0	21.95	34.20
420.	IWO	PORT HARCOURT	611.0	21.85	34.05
421.	ONDO	PORT HARCOURT	498.0	18.42	28.40
422.	IKIRUN	PORT HARCOURT	638.0	22.68	35.25
423.	SHAGAMU	PORT HARCOURT	646.0	22.92	35.80
424.	OKITIPUPA	PORT HARCOURT	473.0	17.66	27.15
425.	OSHOGBO	PORT HARCOURT	617.0	22.04	34.35
426.	ILESHA	PORT HARCOURT	585.0	21.06	32.75
427.	ILARO	PORT HARCOURT	757.0	26.29	41.35
428.	IKARE	PORT HARCOURT	496.0	18.36	28.30

429.	IKOLE	PORT HARCOURT	551.0	20.03	31.05
430.	IJERO EKITI	PORT HARCOURT	572.0	20.67	32.10
431.	OYO	PORT HARCOURT	645.0	23.16	36.20
432.	IJEBU IJESHA	PORT HARCOURT	595.0	21.37	33.25
433.	OGBOMOSHO	PORT HARCOURT	651.0	23.04	36.05
434.	IKERRE	PORT HARCOURT	513.0	18.88	29.15
435.	AKURE	PORT HARCOURT	501.0	18.51	28.55
436.	ADO EKITI	PORT HARCOURT	529.0	19.36	29.95
437.	OWO	PORT HARCOURT	451.0	16.99	26.05
438.	ERUWA	PORT HARCOURT	701.0	24.59	38.55
439.	ABUDU	PORT HARCOURT	277.0	11.70	17.35
440.	AGBOR	PORT HARCOURT	262.0	11.24	16.60
441.	SABONGIDA ORA	PORT HARCOURT	449.0	16.98	25.95
442.	AUCHI	PORT HARCOURT	379.0	14.80	22.45
443.	BENIN	PORT HARCOURT	331.0	20.20	20.05
444.	IGARRA	PORT HARCOURT	409.0	15.71	23.95
445.	SAPELE	PORT HARCOURT	381.0	14.86	22.55
446.	UBIAJA	PORT HARCOURT	322.0	13.07	19.60
447.	UGHELLI	PORT HARCOURT	356.0	14.10	21.30
448.	WARRI	PORT HARCOURT	389.0	15.11	22.95
449.	AWKA	PORT HARCOURT	203.0	12.60	13.18
450.	NSUKKA	PORT HARCOURT	273.0	17.13	17.15
451.	ONITSHA	PORT HARCOURT	192.0	13.50	12.52
452.	ENUGU	PORT HARCOURT	274.0	15.50	17.20
453.	AWGU	PORT HARCOURT	206.0	9.54	13.36
454.	ABA	PORT HARCOURT	64.0	5.45	4.48
455.	UMUAHIA	PORT HARCOURT	119.0	6.90	8.14
456.	OKIGWI	PORT HARCOURT	171.0	10.51	11.26
457.	ORLU	PORT HARCOURT	151.0	10.47	10.06
458.	OWERRI	PORT HARCOURT	113.0	9.55	7.78
459.	AFIKPO	PORT HARCOURT	199.0	9.33	12.94
460.	ABAK	PORT HARCOURT	112.0	6.68	7.72
461.	AKAMKPA	PORT HARCOURT	134.0	6.35	9.04
462.	CALABAR	PORT HARCOURT	204.0	9.48	13.24
463.	EKET	PORT HARCOURT	112.0	11.80	7.72
464.	ETINAM	PORT HARCOURT	143.0	9.00	9.58
465.	IKOT EKPENE	PORT HARCOURT	106.0	7.61	7.36
466.	ITU	PORT HARCOURT	144.0	8.14	9.64
467.	IKOM	PORT HARCOURT	369.0	17.50	21.95
468.	OBUBRA	PORT HARCOURT	295.0	12.25	18.25
469.	OBUDU	PORT HARCOURT	487.0	18.08	27.85
470.	OGOJA	PORT HARCOURT	383.0	14.92	22.65
471.	OPOBO	PORT HARCOURT	67.0	5.04	3.35
472.	ORON	PORT HARCOURT	157.0	11.76	9.85
473.	UYO	PORT HARCOURT	128.0	9.56	8.40
474.	AHOADA	PORT HARCOURT	61.0	5.50	4.27
475.	YENEGOA	PORT HARCOURT	109.0	6.59	7.54
476.	BORI	PORT HARCOURT	43.0	4.59	3.01
477.	ABAKALIKI	PORT HARCOURT	260.0	11.18	16.50
478.	IBADAN	CALABAR PORT	675.0	29.48	39.25
479.	IFE	CALABAR PORT	657.0	11.18	16.50
480.	ABEOKUTA	CALABAR PORT	785.0	27.14	44.75
481.	IJEBU ODE	CALABAR PORT	702.0	25.65	40.60
482.	IWO	CALABAR PORT	699.0	24.53	40.45

483.	ONDO	CALABAR PORT	586.0	21.09	34.58
484.	IKIRUN	CALABAR PORT	726.0	25.35	41.80
485.	SHAGAMU	CALABAR PORT	719.0	27.44	41.45
486.	OKITIPUPA	CALABAR PORT	561.0	20.33	33.55
487.	OSHOGBO	CALABAR PORT	705.0	24.71	40.75
488.	ILESHA	CALABAR PORT	673.0	25.27	39.15
489.	ILARO	CALABAR PORT	845.0	28.97	47.75
490.	IKARE	CALABAR PORT	584.0	21.03	34.75
491.	IKOLE	CALABAR PORT	639.0	22.17	37.45
492.	IJERO EKITI	CALABAR PORT	660.0	23.34	38.50
493.	OYO	CALABAR PORT	742.0	25.84	42.60
494.	IJEBU IJESHA	CALABAR PORT	683.0	24.04	39.65
495.	OGBOMOSHO	CALABAR PORT	739.0	25.15	42.45
496.	IKERRE	CALABAR PORT	601.0	21.55	35.55
497.	AKURE	CALABAR PORT	589.0	21.19	34.95
498.	ADO EKITI	CALABAR PORT	617.0	22.04	36.45
499.	OWO	CALABAR PORT	539.0	23.25	32.45
500.	ERUWA	CALABAR PORT	789.0	27.27	44.95
501.	ABUDU	CALABAR PORT	286.0	11.97	19.80
502.	AGBOR	CALABAR PORT	350.0	16.87	23.00
503.	SABONGIDA ORA	CALABAR PORT	537.0	19.60	32.35
504.	AUCHI	CALABAR PORT	467.0	17.48	28.85
505.	BENIN	CALABAR PORT	419.0	18.26	26.45
506.	IGARRA	CALABAR PORT	479.0	18.39	30.35
507.	SAPELE	CALABAR PORT	469.0	17.54	28.95
508.	UBIAJA	CALABAR PORT	410.0	15.74	26.00
509.	UGHELLI	CALABAR PORT	444.0	16.78	27.70
510.	WARRI	CALABAR PORT	477.0	17.78	29.35
511.	AWKA	CALABAR PORT	271.0	11.52	19.05
512.	NSUKKA	CALABAR PORT	345.0	17.48	20.75
513.	ONITSHA	CALABAR PORT	280.0	12.16	19.50
514.	ENUGU	CALABAR PORT	287.0	14.70	17.85
515.	AWGU	CALABAR PORT	234.0	11.49	17.04
516.	ABA	CALABAR PORT	140.0	8.15	11.40
517.	UMUAHIA	CALABAR PORT	177.0	8.66	11.62
518.	OKIGWI	CALABAR PORT	225.0	12.50	14.50
519.	ORLU	CALABAR PORT	269.0	11.46	16.95
520.	OWERRI	CALABAR PORT	201.0	9.89	15.06
521.	AFIKPO	CALABAR PORT	155.0	7.99	10.30
522.	ABAK	CALABAR PORT	92.0	5.89	8.44
523.	AKAMKPA	CALABAR PORT	40.0	4.20	2.80
524.	EKET	CALABAR PORT	42.0	5.92	4.94
525.	ETINAM	CALABAR PORT	92.0	4.99	8.44
526.	IKOT EKPENE	CALABAR PORT	32.0	4.76	8.92
527.	ITU	CALABAR PORT	94.0	4.84	6.58
528.	IKOM	CALABAR PORT	152.0	9.30	10.12
529.	OBUBRA	CALABAR PORT	163.0	8.24	10.78
530.	OBUDU	CALABAR PORT	270.0	11.97	17.00
531.	OGOJA	CALABAR PORT	240.0	13.50	15.40
532.	OPOBO	CALABAR PORT	114.0	6.91	9.84
533.	ORON	CALABAR PORT	24.0	4.50	4.50
534.	UYO	CALABAR PORT	76.0	6.60	7.32
535.	PORT HARCOURT	CALABAR PORT	181.0	8.47	13.86
536.	AHOADA	CALABAR PORT	242.0	10.64	17.52

537.	DEGEMA	CALABAR PORT	286.0	11.97	19.80
538.	YENEGOA	CALABAR PORT	290.0	12.10	20.00
539.	BORI	CALABAR PORT	181.0	8.78	13.86
540.	ABAKALIKI	CALABAR PORT	206.0	14.75	13.36
541.	IKEJA RAIL	LAGOS PORT	18.0	4.31	4.31
542.	ABEOKUTA RAIL	LAGOS PORT	101.0	5.71	5.71
543.	ILARO RAIL	LAGOS PORT	79.0	5.26	5.26
544.	IBADAN RAIL	LAGOS PORT	197.0	7.36	7.36
545.	OSHOGBO RAIL	LAGOS PORT	297.0	9.21	9.21
546.	IKIRUN RAIL	LAGOS PORT	303.0	9.64	9.64
547.	ABA RAIL	P. H. PORT	63.0	5.01	5.01
548.	UMUAHIA RAIL	P. H. PORT	113.0	5.96	5.96
549.	ENUGU RAIL	P. H. PORT	243.0	8.21	8.21
550.	IDAH RIVER	P. H. PORT	502.0	10.28	10.28
551.	AGENEBODE RIVER	P. H. PORT	502.0	10.28	10.28
552.	ONITSHA RIVER	P. H. PORT	389.0	7.97	7.97
553.	YENEGOA RIVER	P. H. PORT	123.0	4.20	4.20
554.	IDAH RIVER	WARRI PORT	426.0	9.94	9.94
555.	AGENEBODE RIVER	WARRI PORT	426.0	9.94	9.94
556.	ONITSHA RIVER	WARRI PORT	313.0	7.24	7.24
557.	LAGOS PORT	ONE DESTINATION	NIL	1.00	1.00
558.	P. H. PORT	ONE DESTINATIOPN	NIL	1.00	1.00
559.	CALABAR PORT	ONE DESTINATION	NIL	1.00	1.00
560.	SAPELE PORT	ONE DESTINATION	NIL	1.00	1.00
561.	WARRI PORT	ONE DESTINATION	NIL	1.00	1.00